# PHYSICS

MAIN BOOK

FIRST TERM

EL-MOASSER

By A Group Of Supervisors

Interactive E-learning Application

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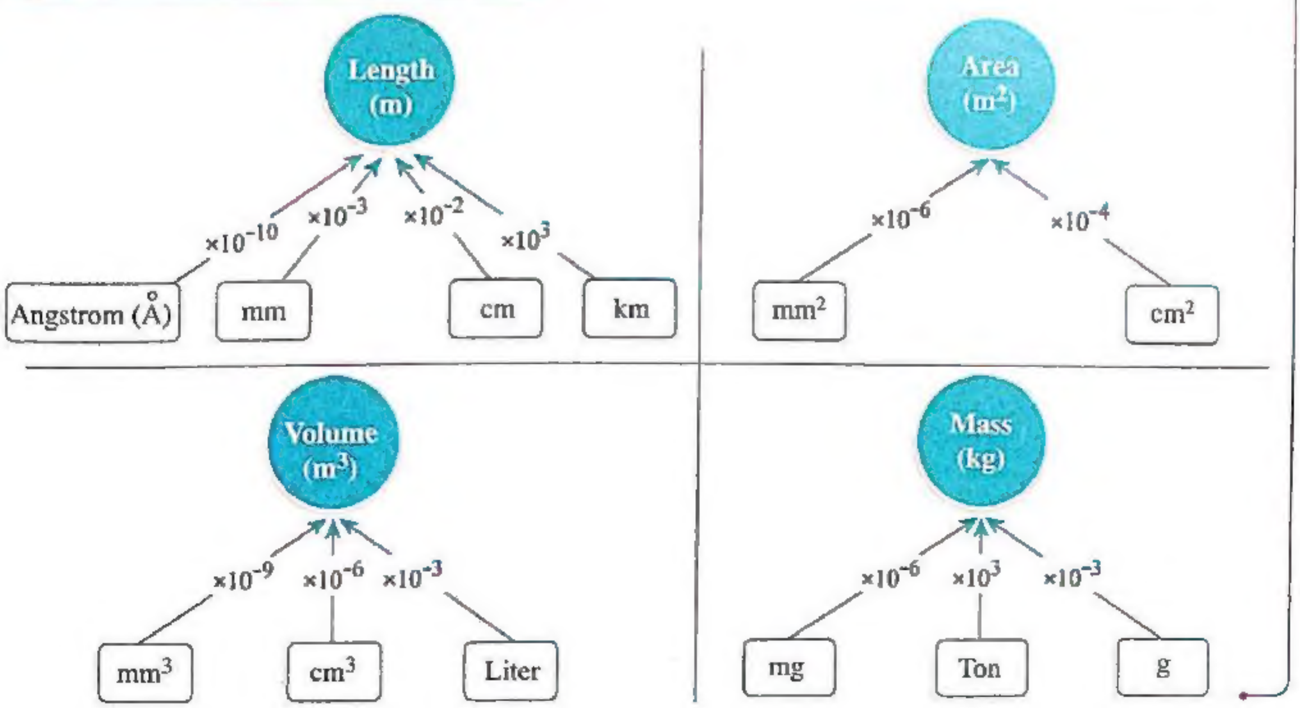
# CONTENTS

## Important physical and mathematical basics

### 1 Common SI prefixes

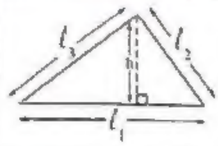
| Prefix | Abbreviation | Meaning |
|---|---|---|
| Femto | f | $10^{-15}$ |
| Pico | p | $10^{-12}$ |
| Nano | n | $10^{-9}$ |
| Micro | μ | $10^{-6}$ |
| Milli | m | $10^{-3}$ |
| Centi | c | $10^{-2}$ |
| Deci | d | $10^{-1}$ |
| Kilo | k | $10^{3}$ |
| Mega | M | $10^{6}$ |
| Giga | G | $10^{9}$ |
| Tera | T | $10^{12}$ |

### 2 Conversion of some units

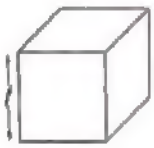


## 3 Perimeters, areas and volumes of some geometric shapes

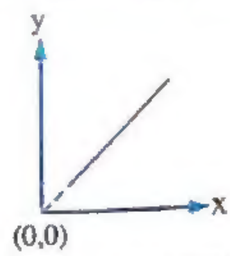
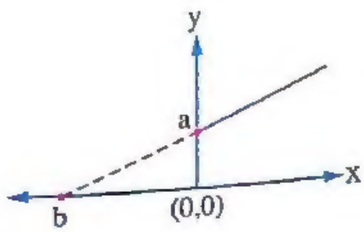
**A. Plane geometric shapes :**

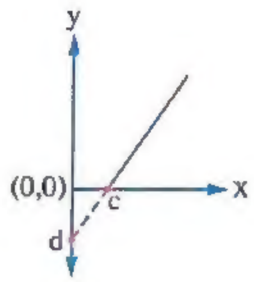
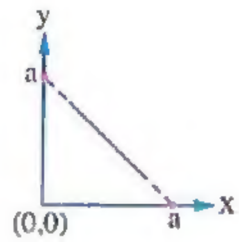
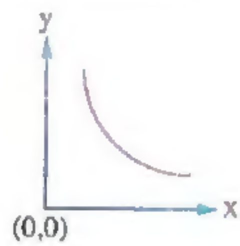
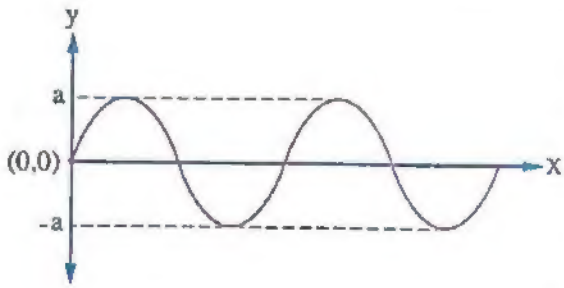
| Figure | Square | Rectangle | Triangle | Circle |
|---|---|---|---|---|
| **Geometrical shape** |  |  |  |  |
| **Perimeter** | $4\ell$ | $2(\ell_1+\ell_2)$ | $\ell_1+\ell_2+\ell_3$ | $2\pi r$ |
| **Area (A)** | $\ell^2$ | $\ell_1 \times \ell_2$ | $\frac{1}{2}\ell_1 \times h$ | $\pi r^2$ |

**B. Solid geometric shapes :**

| Figure | Cube | Cuboid | Sphere | Cylinder |
|---|---|---|---|---|
| **Geometrical shape** |  |  |  |  |
| **Volume (V)** | $\ell^3$ | $\ell_1 \times \ell_2 \times \ell_3$ | $\frac{4}{3}\pi r^3$ | $\pi r^2 \times h$ |

## 4 Graphical representations of some relations between two variables

| Relation | Graph |
|---|---|
| $y = mx$<br>- At x = zero $\Rightarrow$ y = zero<br>* The straight line passes by the origin (0, 0)<br>Slope $= \frac{\Delta y}{\Delta x} = m$ (Direct relation) |  |
| $y = a + mx$<br>- At x = zero $\Rightarrow$ y = a (positive value)<br>* The straight line intersects y-axis at point (a).<br>- At y = zero, x = b (negative value) $= -\frac{a}{m}$<br>Slope $= \frac{\Delta y}{\Delta x} = m$ |  |

| | |
|---|---|
| $y = mx - d$<br>- At y = zero $\Rightarrow x = \frac{d}{m} = c$ (positive value)<br>* The straight line intersects x-axis at point (c).<br>- At x = zero $\Rightarrow$ $y = -d$ (negative value)<br>**Slope** $= \frac{\Delta y}{\Delta x} = m$ |  |
| $y = a - x$<br>- The sum of the two quantities x, y at any point = constant value (a)<br>- At x = zero $\Rightarrow$ y = a (constant value)<br>- At y = zero $\Rightarrow$ x = a (constant value)<br>**Slope** $= \frac{\Delta y}{\Delta x} = -1$ |  |
| $y = \frac{a}{x}$<br>- The product of two quantities x, y at any point equals constant value (a).<br>(Inverse relation) |  |
| $y = a \sin (x)$<br>- The value of (y) varies between (a, – a) with the change of x. |  |

## The used physical quantities, their symbols and units of measurement

| Physical quantity | Symbol | Unit of measurement | |
|---|---|---|---|
| Displacement or distance | d | meter | m |
| Amplitude | A | meter | m |
| Wavelength | $\lambda$ (lamda) | meter | m |
| Frequency | $\upsilon$ (Neo) | hertz = second$^{-1}$ | Hz = $s^{-1}$ |
| Time | t | second | s |
| Periodic time | T | second | s |
| Wave velocity | v | meter/second | m/s |
| Refractive index | n | Dimensionless quantity | |
| Speed of light in space | c | meter/second | m/s |
| Angle of incidence or reflection | $\phi$ | degree | deg |
| Angle of refraction | $\theta$ | degree | deg |
| Critical angle | $\phi_c$ | degree | deg |
| The apex angle of a prism | A | degree | deg |
| Angle of deviation | $\alpha$ | degree | deg |
| Minimum angle of deviation | $\alpha_o$ | degree | deg |
| Dispersive power of the prism | $\omega_\alpha$ | Dimensionless quantity | |
| Mass | m | kilogram | kg |
| Volume | $V_{ol}$ | meter$^3$ | $m^3$ |
| Density | $\rho$ | kilogram/meter$^3$ | $kg/m^3$ |
| Force | F | Newton = kilogram.meter/second$^2$ | N = $kg.m/s^2$ |
| Area | A | meter$^2$ | $m^2$ |
| Free fall acceleration | g | meter/second$^2$ | $m/s^2$ |
| Viscosity coefficient | $\eta_{vs}$ | Newton.second/meter$^2$ = kilogram/meter.second | $N.s/m^2$ = kg/m.s |
| Mass flow rate | $Q_m$ | kilogram/second | kg/s |
| Volume flow rate | $Q_v$ | meter$^3$/second | $m^3/s$ |

# Unit One

## Waves



CHAPTER

# 1 Wave Motion

Lesson 1 | Oscillatory Motion.

Lesson 2 | Wave Motion.

► Test on Chapter 1.

## Chapter objectives

By the end of this Chapter, the student should be able to:

- Recognize the meaning of wave motion.
- Recognize the concept of complete oscillation, amplitude, frequency and periodic time.
- Mention the types of waves.
- Identify the conditions for obtaining mechanical waves.
- Carry out experiments to represent the nature of transverse waves and longitudinal waves.
- Compare between transverse and longitudinal waves.
- Deduce the relation between speed of propagation, frequency and wavelength of a wave.
- Compare between mechanical and electromagnetic waves.
- Acquire the skills to solve problems using the mathematical relations in this chapter.


Chapter 1

Lesson One

# Oscillatory Motion

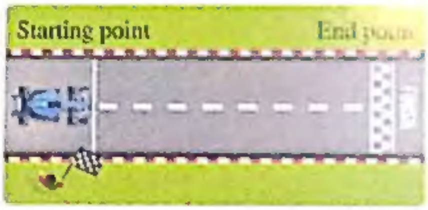
⊙ You have studied that motion can be classified into two types :

Examples

**1 Translational motion**

It is a motion between two different points, a starting point and an end point.

**Motion in a straight line**




**Motion in a curved path (Projectile motion)**

**2 Periodic motion**

It is a motion that gets repeated regularly through equal intervals of time.

**Oscillatory motion**

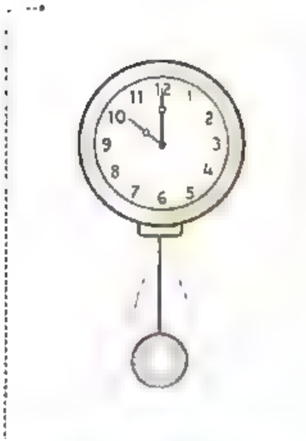
**Wave motion**

- **In this chapter, we will study the wave motion, but first, we have to discover some important concepts through studying the oscillatory motion.**

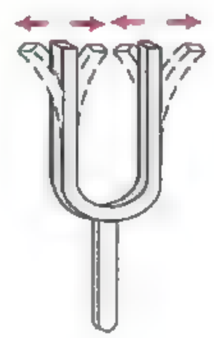
## Oscillatory motion

- If a body moves periodically on both sides of a fixed point, whether its motion is in a straight line or in a curved path, this motion is called an oscillatory motion such as the oscillation of :

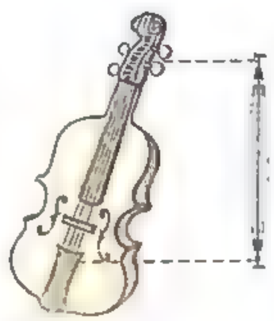
**The oscillatory motion :-**
It is the motion of a vibrating body about its rest position or its equilibrium position that gets repeated through equal intervals of time.



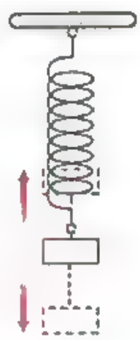

**Simple pendulum (Clock pendulum)**



**Vibrat[illegible] tuning fork**



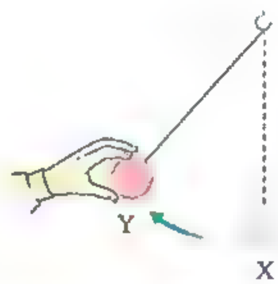
**[illegible]g string ([illegible]iolin strings)**



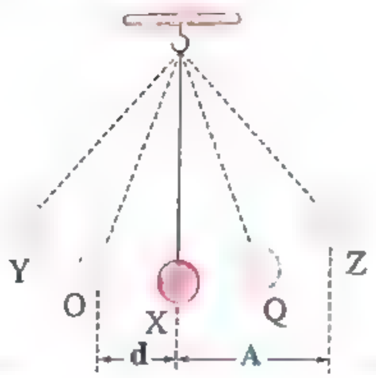
**Plumb or bob suspended to a spring (Yoyo)**

- **In the following, we will study the oscillatory motion thr[illegible] [illegible]motion of a simple pendulum:**

When a bob (suspended weight) of a pendulum is displaced sideways its resting position (point X) towards point Y, it will be subjected to a restoring force due to gravity, therefore when releasing the pendulum, it vibrates back and forth on both sides of its equilibrium position and repeats its motion in regular time intervals.




- To study oscillatory and wave motions, we must know some initial terms and concepts, these physical concepts will be explained using a simple pendulum.




## Displacement (d)

## Amplitude (A)

- When a pendulum is oscillating, its bob moves sideways its rest position (point X) towards any point in its path of motion such as point O or Q where the distance between this point and the equilibrium position is called **displacement (d)**.

- When the weight of the pendulum is displaced from point X to point Y or Z and left to oscillate, so it moves between the two points (Y, Z) where the maximum displacements of the pendulum away from its equilibrium position are equal in both sides (XY = XZ) and is called the **amplitude (A).**

i.e

**The displacement of a vibrating body :**
It is the distance travelled by an oscillating body from its rest or equilibrium position at any moment.

- It is a vector quantity.
- Its measuring unit is **meter (m).**

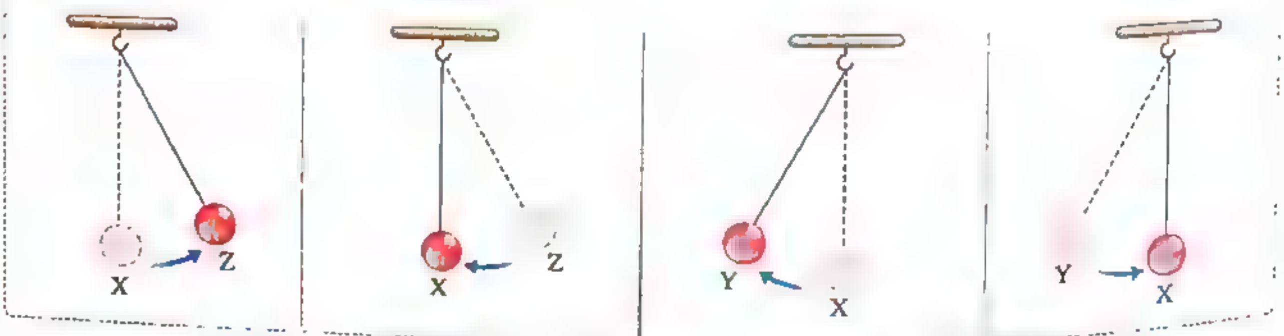
**The amplitude (A) :**
the maximum displacement of an ilating body away from its rest or equilibrium positi

- It is a
- Its mea s **meter (m).**

## 3 Complete oscillation

- When observing the motion of the pendulum bob starting from point X in a certain direction until it returns back to the same point again moving in the same direction, so the pendulum has made a complete oscillation where its path of motion can be represented as follows:

1. X → Z
2. Z → X
3. X → Y
4. Y → X



Hence, the pendulum bob passes by point X two successive times in the same direction with the same velocity, *i.e.* the body has the same **phase**.

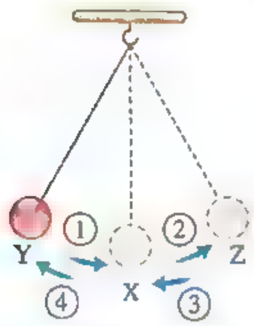
**Enrichment information**

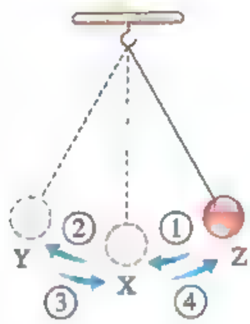
*The phase :* It is the state of position, velocity and direction of the motion of the body at a certain instant.

- **If the motion of the body has been observed starting from:**

| **Point (Y)** | **Point (Z)** |
|---|---|
| It makes one complete oscillation at the instant of passing again through | |
| **Point (Y)** | **Point (Z)** |

**As follows**




| | |
|---|---|
| Y ⟶ X ⟶ Z ⟶ X ⟶ Y | Z ⟶ X ⟶ Y ⟶ X ⟶ Z |

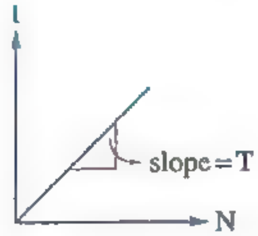
- **Thus, the complete vibration (oscillation) is defined as :**

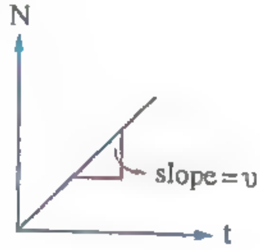
**Complete oscillation:**

It is the motion of an oscillating body during a period of time when it passes through a certain point in its path of motion two successive times in the same direction.

| **4** The periodic time (T) | **5** The frequency ($\upsilon$) |
|---|---|
| **The definition** | |
| The time taken by a vibrating body to pass by the same point two successive times in the same direction (to make a complete oscillation). | The number of complete oscillations made by a vibrating body during one second. |
| **The mathematical relation** | |
| $T = \frac{t \text{ (Total time in seconds)}}{N \text{ (Number of complete oscillations)}}$ $= 4 \times$ The time of an amplitude | $\upsilon = \frac{N \text{ (Number of complete oscillations)}}{t \text{ (Total time in seconds)}} = \frac{1}{4 \times \text{The time of an amplitude}}$ |
| **The measuring unit** | |
| **Second (s)** which is equivalent to **Hertz**$^{-1}$ **(Hz**$^{-1}$**)** | **Hertz (Hz)** which is equivalent to **second**$^{-1}$ **(s**$^{-1}$**)** |

**The graph of N versus t**




**The relation between frequency (υ) and periodic time (T)**

$T = \frac{t}{N}$ , $\because \upsilon = \frac{N}{t}$

$\boxed{T = \frac{1}{\upsilon}}$ **Or** $\therefore \boxed{\upsilon = \frac{1}{T}}$

**i.e**

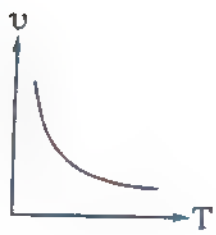
Frequency = The reciprocal of the periodic time, so frequency is inversely proportional to periodic time.

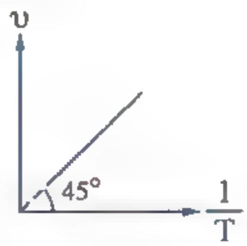
- **From the previous, we can represent the graphs of:**

**Frequency versus periodic time (υ - T)**

**Frequency versus the reciprocal of the periodic time ($\upsilon$ - $\frac{1}{T}$)**

**as follows**




$$\text{Slope} = \frac{\Delta \upsilon}{\Delta (\frac{1}{T})} = 1$$

Notice that the angle = 45° only if the two coordinates are drawn with the same scale

## Notes :

(1) **The motion of the pendulum bob** from point X to point Z represents a quarter of a complete oscillation.

(2) **The time** taken by the bob of the pendulum to move from point X to point Z equals $\frac{1}{4}$ the periodic time.

(3) **The displacement** of the pendulum bob from point X to point Z equals the amplitude.

### Enrichment information

In the ideal simple pendulum, the periodic time (T) depends only on the length ($\ell$) of the thread when the acceleration due to gravity (g) is constant, where: $T = 2\pi\sqrt{\frac{\ell}{g}}$

## Simple harmonic motion (SHM)

- Simple harmonic motion is a type of periodic motion such as the motion of a simple pendulum or a body fixed to a spring coil which can be represented by a sinusoidal curve (sine wave) as follows:

* To clarify the simple harmonic motion, we carry out the following experiment:

### Enrichment information

⊙ In simple harmonic motion, there is a force affecting the body (restoring force) whose magnitude increases as the distance between the vibrating body and its initial position of equilibrium increases and it has a direction that is always toward the initial position of equilibrium.

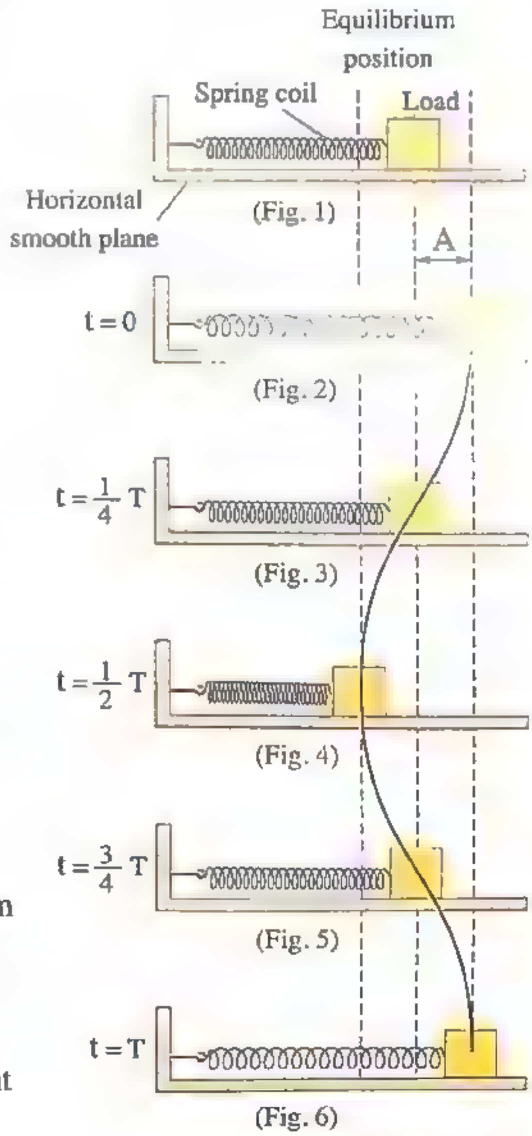
1. **Put a load** on a horizontal smooth plane and attach one end of a spring to the load and the other end to the wall (fig. 1).

2. **At pulling** the load to the right, the spring gets displaced a distance A and gets elongated (fig. 2).

3. **When you release the load**, the spring exerts a force on the load, pulling it towards the equilibrium position (fig. 3).

4. When the load reaches the equilibrium position, its velocity becomes a maximum value and the load exceeds the equilibrium position and completes its motion, hence the spring is compressed and the velocity of the load decreases till it reaches zero when the load reaches a displacement (A) equal to its initial displacement (A) in step 2 (fig. 4).

5. When the spring is compressed, the force resulted from the compression of coil turns causes the load to return again to the equilibrium position at which its velocity becomes a maximum value (fig. 5), then the load passes the equilibrium position to make a displacement A for another time (fig. 6).




(Fig. 1)

(Fig. 2)

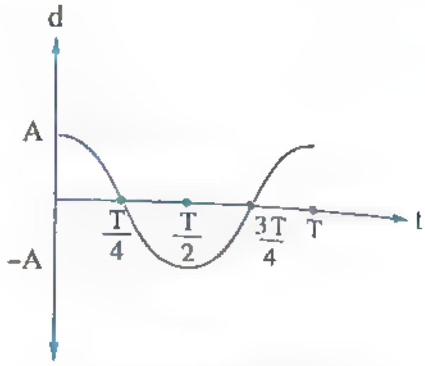
(Fig. 3)

(Fig. 4)

(Fig. 5)

(Fig. 6)

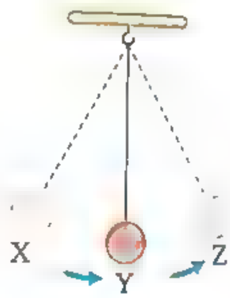
• This motion gets repeated in equal intervals of time, so the relation between the displacement of the load (d) from the equilibrium position and the time (t) can be represented by a sine wave function as shown in the opposite graph:




*sine wave for the simple harmonic motion*

**Example 1**

*In the opposite figure: If the time taken by the pendulum to move from X to Z is 0.8 s, calculate:*




(*a*) The periodic time.

(*b*) The frequency.

(*c*) The number of complete oscillations through 16 s.

(*d*) The time required to make 50 oscillations.

**Solution**

(*a*)

**Clue**

*When the bob of the pendulum moves from X to Z, it covers half a complete oscillation.*

$T = \frac{t}{N} = \frac{0.8}{\frac{1}{2}} = 1.6 \text{ s}$

(*b*) $\upsilon = \frac{1}{T} = \frac{1}{1.6} = 0.625 \text{ Hz}$

(*c*) $N = \frac{t}{T} = \frac{16}{1.6} = 10$ **oscillations**

**Another Solution:** $N = \upsilon t = 0.625 \times 16 = 10$ **oscillations**

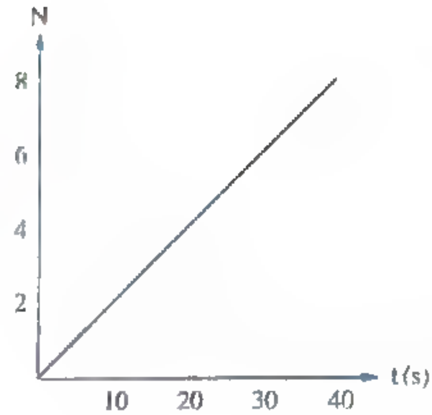
(*d*) $t = NT = 50 \times 1.6 = 80 \text{ s}$

**Another Solution:** $t = \frac{N}{\upsilon} = \frac{50}{0.625} = 80 \text{ s}$

## Example 2

*The opposite graph represents the relation between the number of complete oscillations (N) and the time (t), then the frequency of motion of this body equals .......... .*

ⓐ 0.2 Hz ⓑ 2 Hz ⓒ 5 Hz ⓓ 40 Hz




### Solution

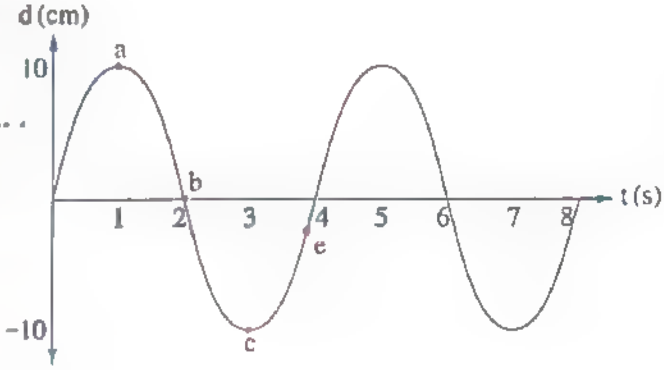
$$\text{Slope} = \frac{\Delta N}{\Delta t} = \frac{8-0}{40-0} = 0.2\ s^{-1}$$

$\because \upsilon = \frac{N}{t}$ $\therefore \upsilon = \text{Slope} = 0.2\ \text{Hz}$

$\therefore$ The correct choice is ⓐ.

## Example 3

*The opposite graph represents the relation between the displacement (d) of an oscillating body and the time (t), then .......... .*




| | The amplitude | The number of complete oscillations per minute |
|---|---|---|
| ⓐ | 10 cm | 15 |
| ⓑ | 20 cm | 15 |
| ⓒ | 10 cm | 20 |
| ⓓ | 20 cm | 20 |

### Solution

t = 1 minute A = ? N = ?

$\because$ The amplitude is the maximum displacement of an oscillating body away from its rest position.

$\therefore$ From the graph:

A = 10 cm

T = 4 s $T = \frac{t}{N}$

Through a minute :

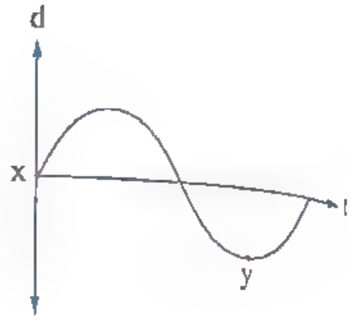
$$N = \frac{t}{T} = \frac{1 \times 60}{4} = 15$$

$\therefore$ The correct choice is ⓐ.

**What if** you are asked to determine at which of the four points a, b, c or e, the object's velocity is greater? **What is your answer?**

**Example 4**

*The opposite graph represents the relation between the displacement (d) and the time (t) for a mass tied to a spring and vibrating with frequency 60 Hz, then the time taken by the mass to pass between the two points x, y is .......... .*




ⓐ $4 \times 10^{-3}$ s
ⓑ $8 \times 10^{-3}$ s
ⓒ $12.5 \times 10^{-3}$ s
ⓓ $25 \times 10^{-3}$ s

**Solution**

$\upsilon = 60$ Hz $\qquad t_{xy} = ?$

**Clue**

*The motion of the mass between the two points x, y represents $\frac{3}{4}$ complete oscillation and hence the time interval taken by the mass to move between them equals $\frac{3}{4}$ T.*

$$T = \frac{1}{\upsilon} = \frac{1}{60}\ \text{s}$$

$$t_{xy} = \frac{3}{4} T = \frac{3}{4} \times \frac{1}{60} = 12.5 \times 10^{-3}\ \text{s}$$

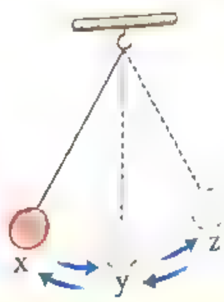
∴ The correct choice is ⓒ.

**What if** you have known that the amplitude of the spring is 2 cm, what is the magnitude of the average velocity of the mass when it vibrates between the two points x, y?

## Test yourself

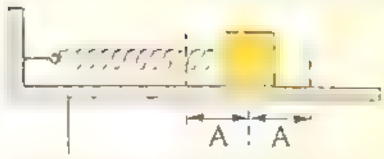
**Choose the correct answer:**

**1** The opposite figure represents an oscillating simple pendulum, so its periodic time equals .......... .




ⓐ the time of motion from x to z
ⓑ the time of motion from y to z
ⓒ double the time of motion from z to y
ⓓ double the time of motion from z to x

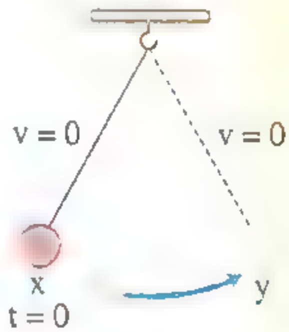
**2** The opposite figure represents a body tied to a spring that makes a simple harmonic motion such that the amplitude of its vibration is A, so when the body makes a complete oscillation, .......... .

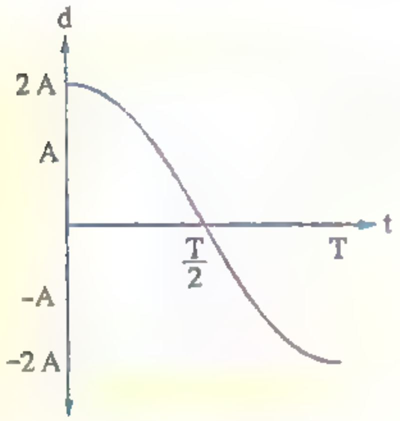



A smooth horizontal surface

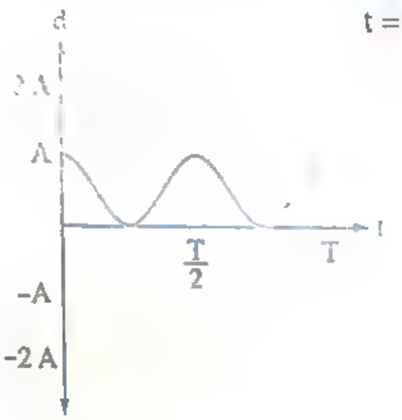
| | Its total displacement | The total distance covered by the body |
|---|---|---|
| ⓐ | 0 | 0 |
| ⓑ | 0 | 4 A |
| ⓒ | 2 A | 0 |
| ⓓ | 2 A | 4 A |

**3** A simple pendulum vibrates with a periodic time T and amplitude A. If the pendulum starts swinging from point x in the direction of point y as shown in the opposite figure, then the graph that represents the relationship between the distance (d) of the bob of the pendulum away from point y and the time (t) is .......... .

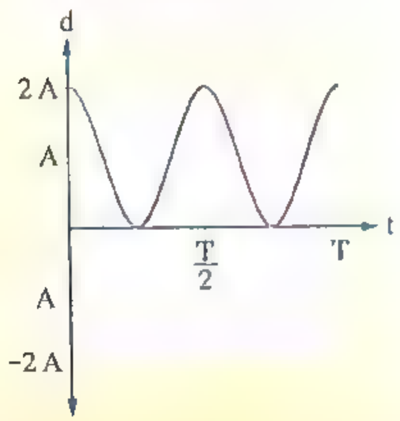


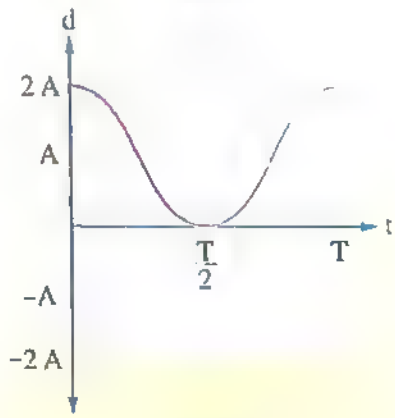

ⓐ




ⓑ



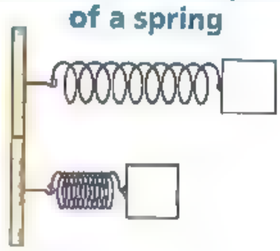

ⓒ



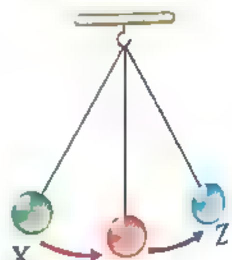

ⓓ

## Energy transformations during the motion of simple pendulum

* Before studying the energy transformations in a simple pendulum, let us remember the concepts of kinetic energy, potential energy and mechanical energy:

| | The concept | Example |
|---|---|---|
| **1** **Kinetic energy** $KE = \frac{1}{2} mv^2$ → | The energy possessed by the body due to its motion | A running man  |
| **2** **Potential energy** $PE = mgh$ → | The energy stored in the body due to its state or position | Elongation and compression of a spring  |
| **3** **Mechanical energy** $E = PE + KE$ → | The summation of the potential energy and the kinetic energy of the body | Pole vault  |

☆ In the following, we will discuss the transformations of energy in a simple pendulum so that when the pendulum bob shown in the opposite figure moves starting from position X, hence:




### At position X

**1** The pendulum bob has the maximum height relative to its equilibrium position.

$v = 0$

$KE = 0$

$E = PE$

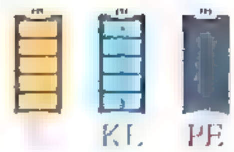

### During its motion from position X to Y

**2**
- The vertical height of the pendulum bob decreases gradually, hence its potential energy decreases.
- Its kinetic energy increases as its velocity increases.

*i.e.* The potential energy gets converted gradually into kinetic energy since the mechanical energy is constant at all positions.

### At position Y (The equilibrium position)

3
- The potential energy of the bob has been completely converted into kinetic energy.
- The velocity of the bob at this position has a maximum value.




### During the motion from position Y to Z

4
- The height of the pendulum bob increases gradually from its equilibrium position, hence its potential energy increases.
- The velocity of the pendulum decreases gradually as its kinetic energy decreases, hence the kinetic energy gets converted gradually into potential energy since the mechanical energy is constant at all positions.


### At position Z

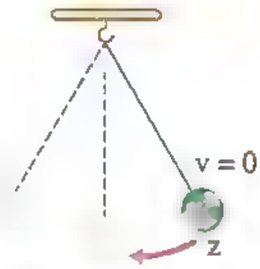
5 The kinetic energy gets converted completely into potential energy.

$v = 0$

$KE = 0$

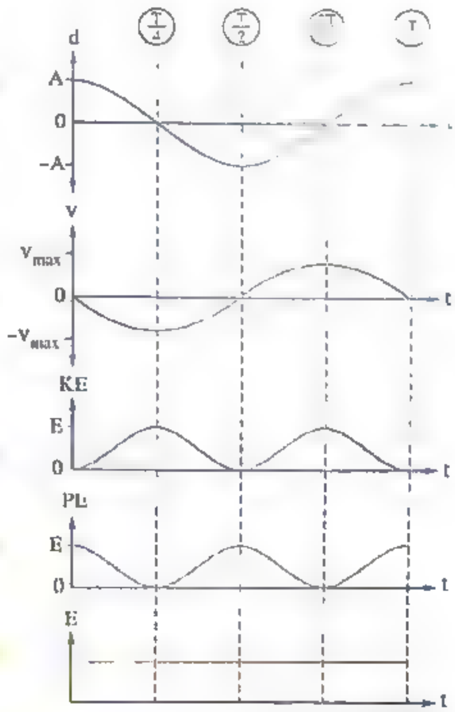
$E = PE$


- In the opposite figure, when the pendulum moves starting from point Z, the following graphs represent the variations of some physical quantities related to the motion of this pendulum as time (t) passes through one complete oscillation:




Equilibrium position

1. The displacement (d) away from the equilibrium position versus time (t).
2. The velocity (v) versus time (t).
3. The kinetic energy (KE) versus time (t).
4. The potential energy (PE) versus time (t).
5. The mechanical energy (E) versus time (t).

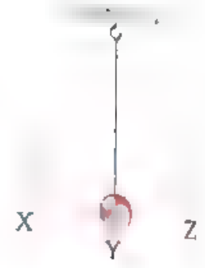


## Note :

- **In the opposite pendulum when the pendulum bob is displaced from point y to x then left to vibrate;**

(1) The velocity of the pendulum at point Y is a maximum value.

(2) The velocity of the pendulum at each of the two points X and Z vanishes.



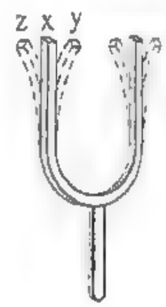

**Hence, we can define the amplitude as follows:**

**The amplitude :**

It is the distance between two successive points in the path of motion of an oscillating body whose velocity becomes a maximum value at one of them and zero at the other.

**Example 1**

*The opposite figure represents an oscillating tuning fork, so the velocity of the fork's arm increases then decreases when it moves from ......... .*




(a) z to x

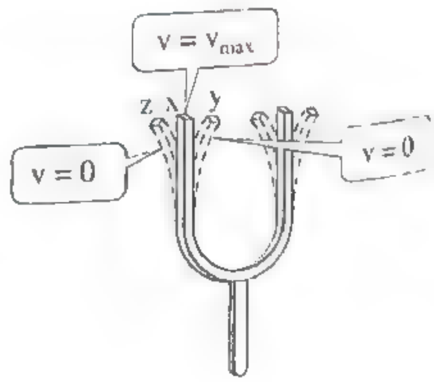
(b) x to y

(c) y to z

(d) x to z then to x

**Solution**

The opposite figure shows the magnitudes of the velocity of the fork's arm at the points x, y and z, it is noticed that the velocity of the fork's arm increases then decreases when it moves from point y to point z or vice versa.

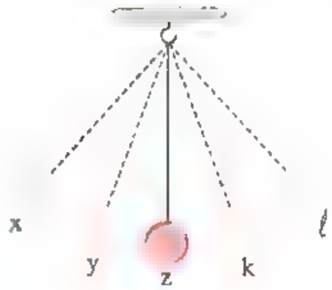



∴ The correct choice is (c).

**What if** you are asked to determine at which position x, y or z, the mechanical energy of the tuning fork is the greater ? **What** is your answer?

**Example 2**

*The opposite figure shows the motion of a simple pendulum where $xy = yz = zk = k\ell$. If the pendulum takes time $t$ to move from x to y, the periodic time is .......... .*




ⓐ 8 t
ⓑ less than 8 t
ⓒ greater than 8 t
ⓓ indeterminable

## Solution

### Clue

*The pendulum moves from x to z with positive acceleration where its velocity increases as it goes down due to the change of its potential energy into kinetic energy, where its average velocity through the displacement yz is greater than through the displacement xy, so the displacement yz takes time less than t and the same for displacement zk, so the time taken to cover the distance xy is greater than half the time of the amplitude*

*i.e. it is greater than $\frac{1}{8}$ the time of complete oscillation.*

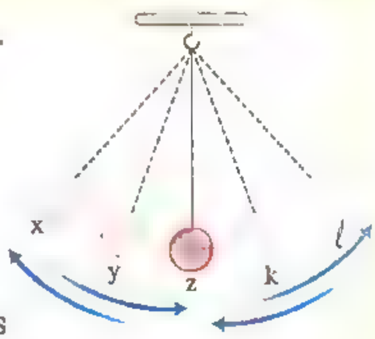
∴ The periodic time for the pendulum is **less than 8 t.**

∴ **The correct choice is ⓑ.**

## 2 Test yourself

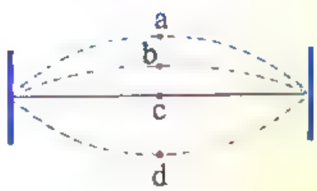
Choose the correct answer:

**1** The opposite figure shows the motion of a simple pendulum. If $xy = yz = zk = k\ell$, so .......... .




ⓐ the kinetic energy at k > The potential energy at x
ⓑ the potential energy at $\ell$ < The potential energy at y
ⓒ the kinetic energy at y = The kinetic energy at k
ⓓ the kinetic energy equals the potential energy at all points

**2** The opposite figure shows a vibrating string, which of the following ratios of potential energy is less than one?




ⓐ $\frac{(PE)_a}{(PE)_c}$
ⓑ $\frac{(PE)_a}{(PE)_d}$
ⓒ $\frac{(PE)_b}{(PE)_d}$
ⓓ $\frac{(PE)_a}{(PE)_b}$

Chapter 1

Questions on Lesson One

# Oscillatory Motion

To watch videos of how to solve questions use the App

Interactive test

The questions signed by ✳ are answered in detail.

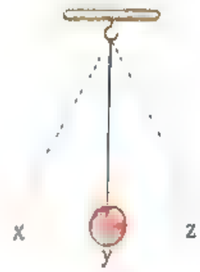
Understand  Apply  Higher Order Thinking Skills

## First Multiple choice questions

1. The motion of a body in a circular path with a constant speed is considered ........ .
   - (a) a periodic motion
   - (b) a simple harmonic motion
   - (c) an oscillatory motion
   - (d) a wave motion

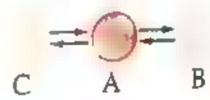
2. The motion of a swing is considered ........ .
   - (a) a translational motion
   - (b) a wave motion
   - (c) an oscillatory motion
   - (d) a circular motion

3. In the opposite figure, the pendulum makes a com oscillation when it moves from ........



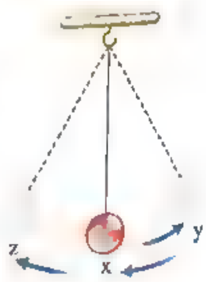

   - (a) x ⟶ y
   - (b) x ⟶ y ⟶ z
   - (c) x ⟶ y ⟶ z ⟶ y
   - (d) x ⟶ y ⟶ z ⟶ y ⟶ x

4. ✳ In the opposite figure, a body moves in an oscillatory motion, so the distance which is moved by the body during a complete oscillation equals ........ .




   - (a) double the distance AB
   - (b) double the distance BC
   - (c) half the distance AC
   - (d) four times the distance BC

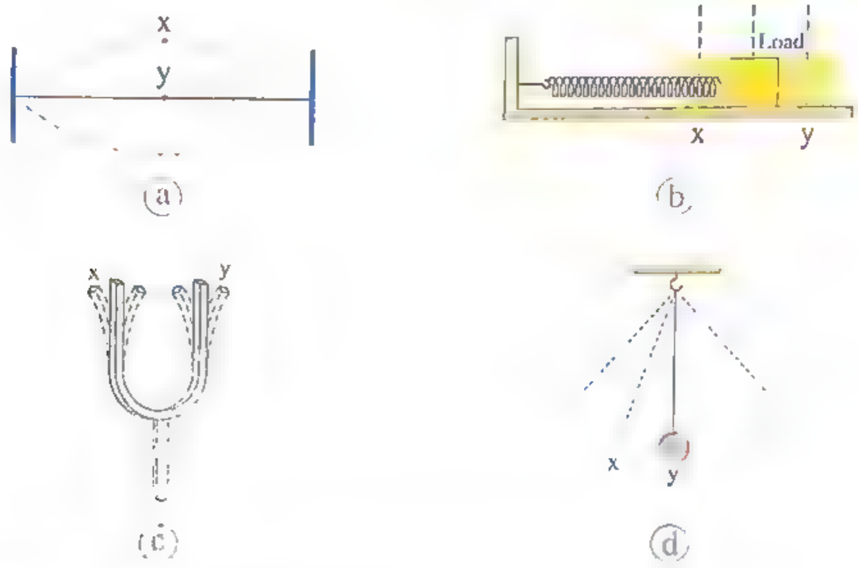
5. The opposite figure shows a simple pendulum vibrating with an amplitude A. If its bob has moved from position x to position y then to position z, the magnitude of displacement of the pendulum bob equals ........ .




   - (a) A
   - (b) 2 A
   - (c) 3 A
   - (d) zero

6. In an oscillatory motion, the ratio between the time of an amplitude and the time of a complete oscillation is ........ .
   - (a) $\frac{2}{1}$
   - (b) $\frac{1}{2}$
   - (c) $\frac{4}{1}$
   - (d) $\frac{1}{4}$

7. In which of the following figures is the distance between the two positions x, y representing the amplitude of vibration?




8. The opposite figure shows a string vibrating with a periodic time T, so the time taken by the string to reach the maximum displacement from its equilibrium position is ........ .

ⓐ $\frac{T}{4}$   ⓑ $\frac{T}{3}$   ⓒ $\frac{T}{2}$   ⓓ T

9. The periodic time of an oscillating simple pendulum is the time taken by the pendulum bob to pass for two successive times through a point in its path when this point is ........ .

ⓐ at the equilibrium position

ⓑ at the maximum displacement away from the equilibrium position

ⓒ between the equilibrium position and the maximum displacement in the positive direction

ⓓ between the equilibrium position and the maximum displacement in the negative direction

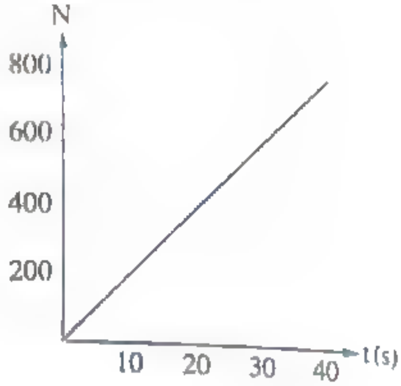
10. ✻ The opposite figure shows a person measuring his pulse rate that is found to be 75 beats per minute. What is the frequency and the periodic time of his heart muscle motion?

| | The frequency | The periodic time |
|---|---|---|
| ⓐ | 0.8 Hz | 0.8 s |
| ⓑ | 0.8 Hz | 1.25 s |
| ⓒ | 1.25 Hz | 0.8 s |
| ⓓ | 1.25 Hz | 1.25 s |

11. ✻ If a vibrating object takes 0.1 s to complete one oscillation, then the number of complete oscillations made by the object during 100 s equals ........ oscillations.

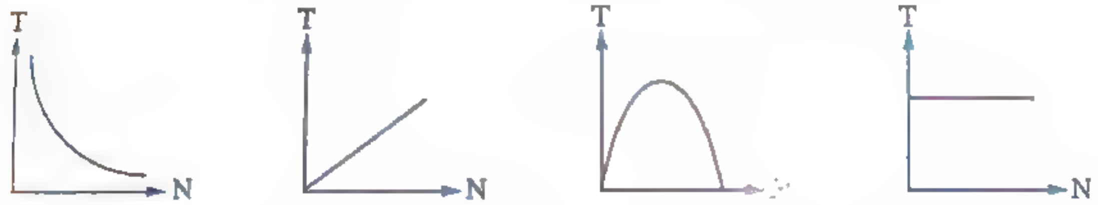
(a) 10 (b) 100 (c) 1000 (d) 10000

12. ✻ The opposite graph represents the relation between the number of oscillations (N) produced from an oscillating source and the time (t) during which those oscillations occur, the frequency of the source equals .......... .



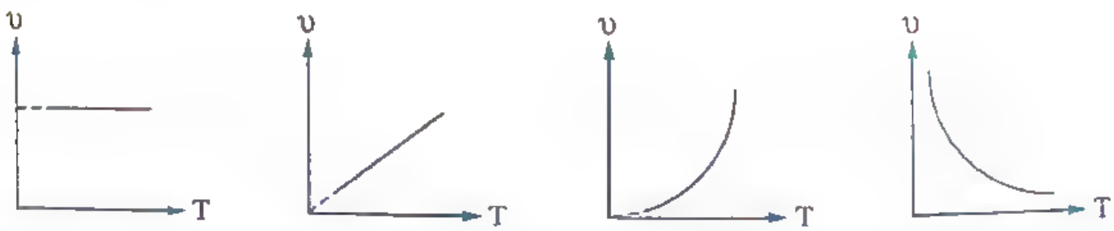

(a) 10 Hz (b) 20 Hz
(c) 40 Hz (d) 800 Hz

13. Which of the following graphs represents the relation between the periodic time (T) of a simple pendulum and the number of complete oscillations (N) made by the pendulum?




(a) (b) (c) (d)

14. Which of the following graphs represents the relation between the frequency ($\upsilon$) and the periodic time (T) of a body making a simple harmonic motion?




(a) (b) (c) (d)

15. ✻ Two simple pendulums (x, y) are oscillating, the ratio between their periodic times $(\frac{T_x}{T_y})$ is $\frac{1}{4}$, then the ratio between their frequencies $(\frac{\upsilon_x}{\upsilon_y})$ equals .......... .

(a) $\frac{1}{4}$ (b) $\frac{1}{2}$ (c) $\frac{4}{1}$ (d) $\frac{2}{1}$

16 ✳ In the opposite figure, if the pendulum takes 1 s to move from point X to point Y, so its frequency equals ......... .


ⓐ 0.5 Hz ⓑ 5 Hz
ⓒ 10 Hz ⓓ 50 Hz

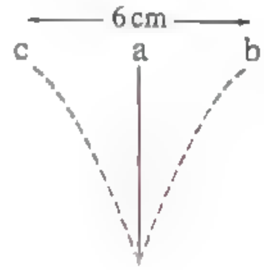
17 ✳ A vibrating body takes 0.01 s to reach its maximum displacement away from its equilibrium position, so its frequency equals ......... .

ⓐ 20 Hz ⓑ 25 Hz ⓒ 50 Hz ⓓ 100 Hz

18 ✳ The ratio between the periodic time and the frequency of a vibrating body equals $\frac{1}{625}$ $s^2$, so the number of oscillations made by the body during 25 s is ......... oscillations.

ⓐ 25 ⓑ 125 ⓒ 425 ⓓ 625

19 ✳ In the opposite figure, a flexible oscillating rod takes time of 0.01 s to move from a to b, then:




(i) Its periodic time ......... .

ⓐ 0.02 s ⓑ 0.04 s
ⓒ 0.06 s ⓓ 0.08 s

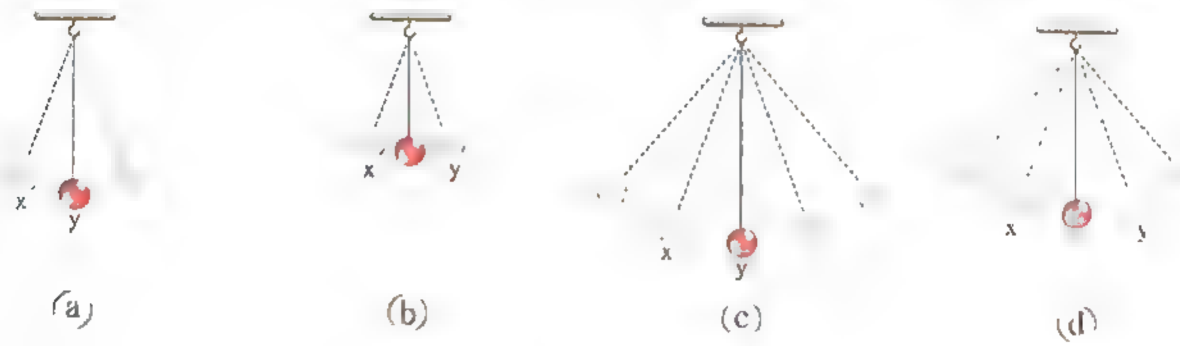
(ii) The amplitude of its oscillation is ......... .

ⓐ 3 cm ⓑ 6 cm ⓒ 9 cm ⓓ 12 cm

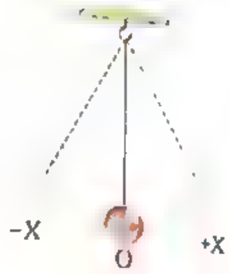
(iii) The average speed of the rod's motion between the two points b, c equals

ⓐ 600 cm/s ⓑ 300 cm/s ⓒ 150 cm/s ⓓ 75 cm/s

20 Which of the following figures represents a simple pendulum that has the lower frequency if the time taken by the bob of the pendulum from point x to point y in each of them is t?



**21** In the opposite figure, a simple pendulum makes a simple harmonic motion of periodic time T. Starting from point + X, the point at which the bob of the pendulum becomes after a time interval of:




(i) 2 T is ………. .

(a) point –X

(b) point + X

(c) point O

(d) between the two points + X, O

(ii) 3.5 T is ………. .

(a) point –X (b) point + X

(c) point O (d) between the two points –X, O

(iii) 5.25 T is ………. .

(a) point + X

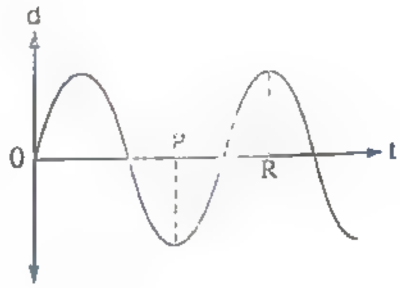
(b) point O

(c) between the two points – X, O

(d) between the two points + X, O

---

**22** The opposite graph represents the relation between the displacement (d) of a vibrating body and the time (t), so the time difference between the two points P, R is ………. .




(a) half the periodic time

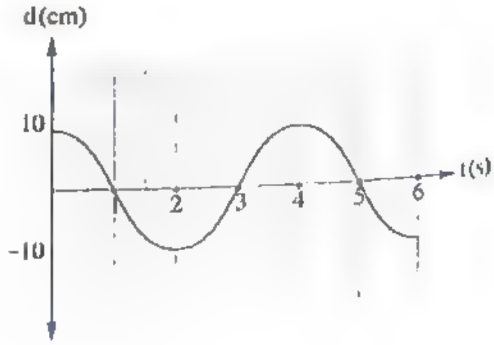
(b) double the periodic time

(c) the periodic time

(d) quarter the periodic time

---

**23** The opposite graph represents the variation of the displacement (d) of a body which makes a simple harmonic oscillation with time (t), then:




(i) The amplitude of its oscillation is equal to ………. .

(a) 5 cm (b) 6 cm

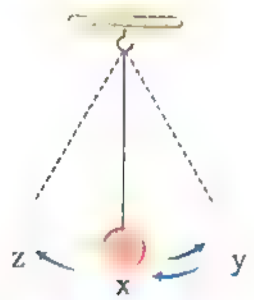
(c) 10 cm (d) 20 cm

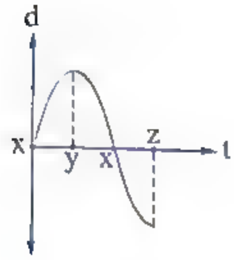
(ii) The periodic time of its motion equals ………. .

(a) 2 s (b) 3 s

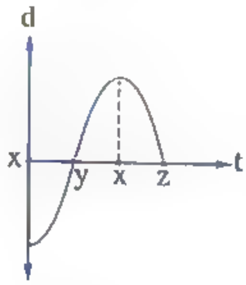
(c) 4 s (d) 6 s

24. ✳ Which of the following graphs represents the relation between the displacement (d) away from point x for the bob of the pendulum shown in the opposite figure and the time (t) when the pendulum moves from point x to y then z ?

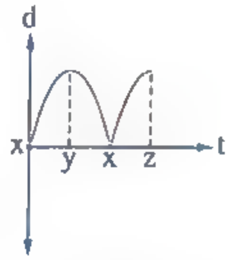


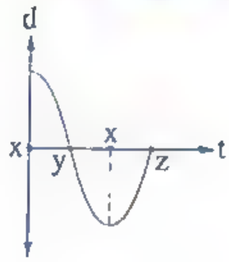

(a)




(b)

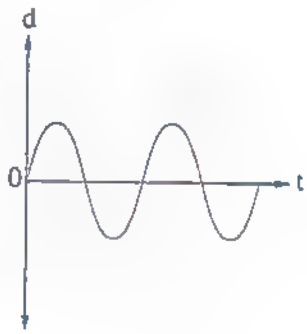


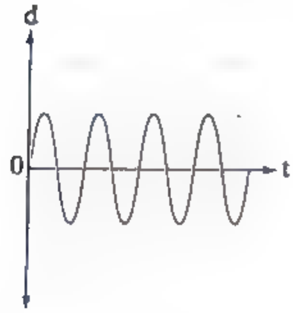

(c)



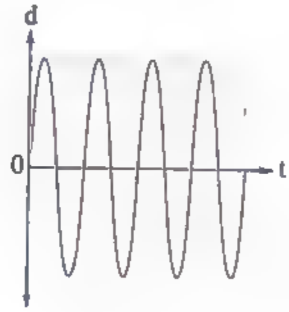

(d)

25. A simple pendulum vibrates with frequency $\upsilon$ and amplitude A, the opposite graph represents the relation between the displacement (d) for the bob of the pendulum and the time (t), if the length of the pendulum string and the work done on the bob are modified to increase both the frequency and the amplitude of vibration to the double, which of the following graphs represents the relation between the displacement (d) and the time (t) for the motion of the pendulum in this case?

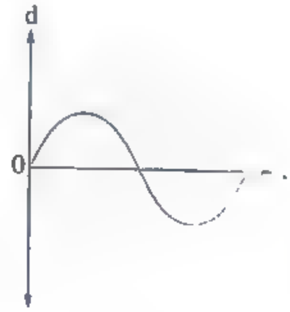



(a)



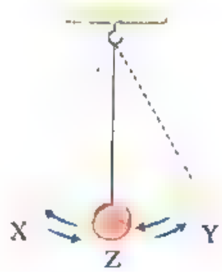

(b)




(c)

(d)

26. In the opposite figure a pendulum vibrates with frequency 0.5 Hz about its equilibrium position (Z), if the pendulum starts its motion from position Y, so through a minute the bob of the pendulum passes by:




(i) position Y .......... times.

(a) 29 (b) 30

(c) 31 (d) 60

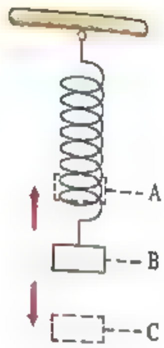
(ii) position Z .......... times.

ⓐ 30
ⓑ 59
ⓒ 60
ⓓ 61

(iii) position X .......... times.

ⓐ 29
ⓑ 30
ⓒ 31
ⓓ 60

27 In the opposite figure, a body suspended to a vertical spring is pulled downwards from point B to point C then left to move a simple harmonic motion. The total mechanical energy of this body when the air resistance is neglected will be .......... .




ⓐ a maximum value at point A
ⓑ a maximum value at point B
ⓒ a minimum value at point B
ⓓ constant at all points

28 ✻ Figure (1) shows a pendulum whose equilibrium position is at y oscillating between the two positions x, z and figure (2) shows graphically the relation between the displacement (d) of the pendulum bob from position x and the time (t), then:

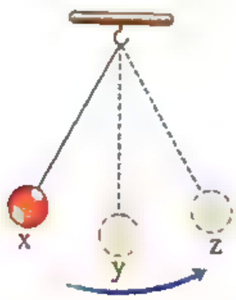



Figure (1)

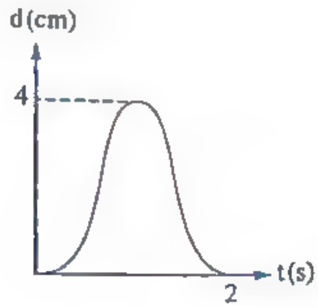



Figure (2)

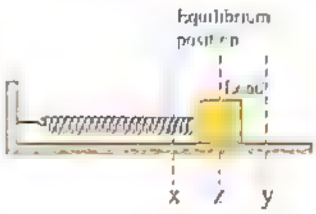
(i) The amplitude of the pendulum equals .......... .

ⓐ 1 cm
ⓑ 2 cm
ⓒ 4 cm
ⓓ 8 cm

(ii) The frequency of the pendulum equals .......... .

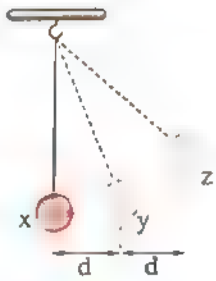
ⓐ 0.25 Hz
ⓑ 0.5 Hz
ⓒ 2 Hz
ⓓ 4 Hz

29 The opposite figure shows a load placed on a smooth horizontal surface connected to a spring coil while moving a simple harmonic motion. if the load passes by position z with a velocity of 0.5 m/s towards the left at a certain instant, what will be the position and the velocity of the load after it completes one and a half oscillation from that instant ?



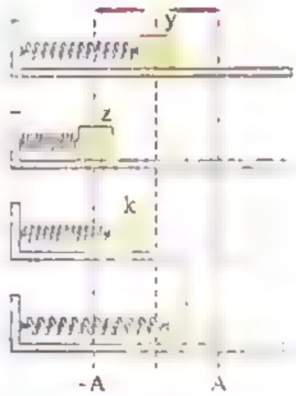

| | Position | Frequency |
|---|---|---|
| (a) | z | 0 |
| (b) | y | 0.5 m/s towards the right |
| (c) | x | 0 |
| (d) | z | 0.5 m/s towards the right |

30 * In the opposite figure, if the time taken by the pendulum to move from position x to y is $t_1$ and the time taken by the pendulum to move from y to z is $t_2$, so .......... .



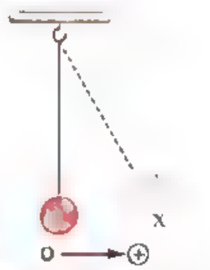

(a) $t_1 = t_2$
(b) $t_1 > t_2$
(c) $t_1 < t_2$
(d) the answer is indetermined

31 The opposite figure represents four positions for a body connected to a spring coil during its vibration, at which position the body has the higher speed?




(a) y
(b) z
(c) k
(d) ℓ

32 * The opposite figure shows a simple pendulum whose bob has been displaced to position x, if the bob of the pendulum is left to move in a simple harmonic motion of periodic time 2 s, the time taken from the moment at which the bob is left to move until it has :



The positive direction of motion

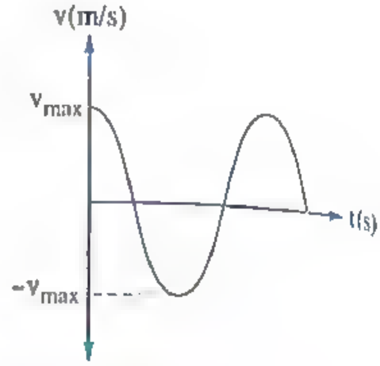
(i) The maximum displacement in the negative direction for the first time equals .......... .

(a) 0.5 s
(b) 1 s
(c) 1.5 s
(d) 2 s

(ii) The maximum speed for the first time equals .......... .

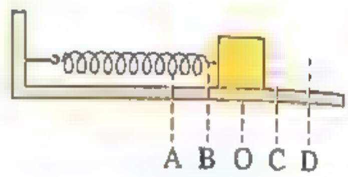
(a) 0.5 s
(b) 1 s
(c) 1.5 s
(d) 2 s

33 The opposite graph represents the relation between the velocity (v) of the bob of a simple pendulum and the time (t) when it is observed starting from .......... .



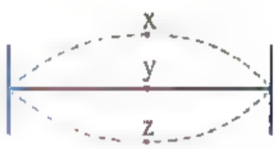

ⓐ its equilibrium position
ⓑ the position of maximum displacement
ⓒ the position at which the bob has the maximum possible potential energy
ⓓ the midpoint between its equilibrium position and its maximum displacement

34 The opposite figure represents a body connected to a spring and vibrating between the two points A, D, then the minimum potential energy of the body is at .......... .



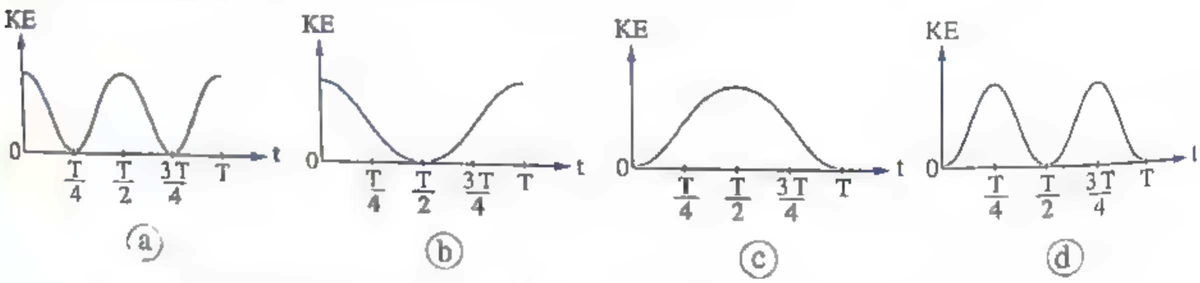

ⓐ point A or point D
ⓑ point O
ⓒ point B
ⓓ point C

35 The opposite figure represents a string vibrating between the two positions x, z, then the kinetic energy of the string is converted gradually into potential energy when the string moves from .......... .

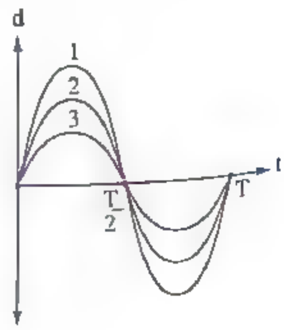



ⓐ x to z
ⓑ y to z
ⓒ z to y
ⓓ x to y

36 ✻ A simple pendulum started a simple harmonic motion from the farthest position away from its equilibrium position at $t = 0$. If the periodic time of the pendulum is T, then which of the following graphs represents the relation between the kinetic energy (KE) of the pendulum bob and the time (t)?




37 ✻ Three identical bodies make simple harmonic motions, the opposite graph represents the relation between the displacement (d) and the time (t) for each of them, so the arrangement of these bodies according to the maximum kinetic energy of the body is ..........



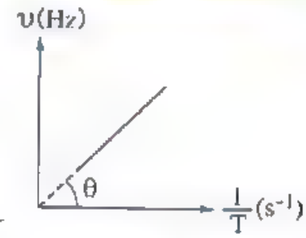

ⓐ $1 > 2 > 3$
ⓑ $2 > 3 > 1$
ⓒ $1 > 3 > 2$
ⓓ $1 = 2 = 3$

## Second Essay questions

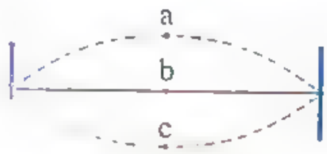
1. **What happens** to the periodic time of a vibrating object when its frequency gets tripled? **Explain your answer.**

2. **Describe** each of the transformations of potential and kinetic energies for the swing shown in the opposite figure through a complete oscillation starting from the equilibrium position.

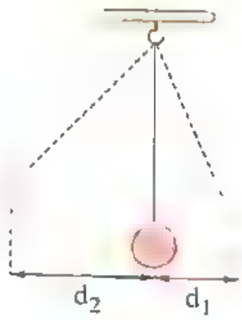
3. The opposite graph represents the relation between the frequency ($\upsilon$) of an oscillatory motion and the reciprocal of its periodic time ($\frac{1}{T}$) when the two coordinates are drawn with the same scale, **what** is the value of angle $\theta$?



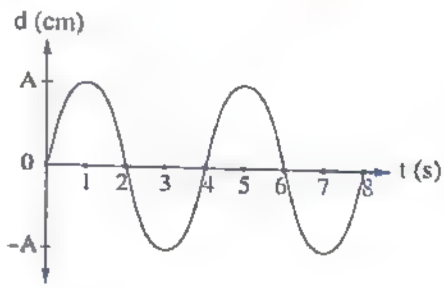

4. The opposite figure shows the motion of a vibrating string:
   (a) **At which point** is the speed of the string maximum?
   (b) **At which point** is the elastic potential energy of the string maximum?
   (c) **Find the ratio between** the taken time of the string motion from b to c and the taken time of its motion from b to a.




5. The opposite figure represents two attempts to move the bob in a simple harmonic motion, in the first attempt when it is displaced for a distance $d_1$ and then left to vibrate and in the second attempt when it is displaced for a distance $d_2$ and then left to vibrate. **What happens to** each of the amplitude, the maximum potential energy and the mechanical energy of the pendulum bob in the second attempt compared to the first attempt?




6. A body suspended by a string is pushed to the right to swing left and right about its original equilibrium position, the opposite graph represents the relation between the displacement (d) starting from the moment of pushing the body and time (t) through 8 s, if we consider that the direction of its motion to the right is the positive direction, then at which moment or moments during this period the body will be:
   (a) moving towards the right with a maximum speed?
   (b) moving towards the left with a maximum speed?
   (c) static instantaneously?

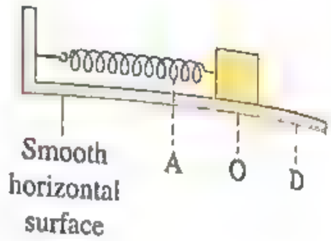


# New Types of questions ?

Understand  Apply  Higher Order Thinking Skills

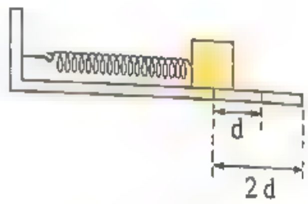
**First : Choose two correct answers in each of the following :**

1. The opposite figure represents a load attached to one of the terminals of a spring undergoing a simple harmonic motion between the two points A, D, so which of the following quantities have its minimum value when the load passes at point O?




ⓐ The elastic potential energy of the load.
ⓑ The displacement of the load away from its equilibrium position.
ⓒ The speed of the load.
ⓓ The mechanical energy of the load.
ⓔ The kinetic energy of the load.

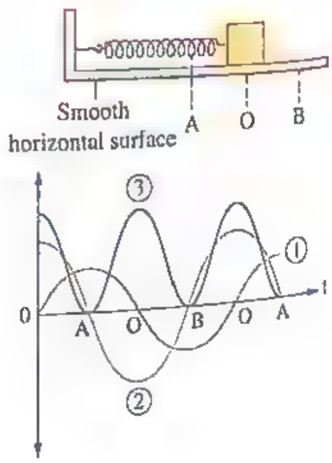
2. The opposite figure represents two cases in which a body undergoes simple harmonic motions, the first is when the body gets displaced for a distance d then left to vibrate and the second is when the body gets displaced for a distance 2 d then left to vibrate, what happens to each of the following in the second case compared to the first ?




ⓐ The amplitude gets doubled.
ⓑ The amplitude gets quadrupled.
ⓒ The speed of the body at its original position becomes greater.
ⓓ The speed of the body at its original position remains unchanged.
ⓔ The mechanical energy of the body has the same value.

**Second : Put in front of each of the following sentences the suitable number of the curve shown in the graph:**

The opposite figure represents a load attached to one of the terminals of a spring undergoing a simple harmonic motion between the two points A, B and the opposite graph represents the relation between some physical quantities for that body on y-axis and time (t) on x-axis, so the curve that represents:




(a) The kinetic energy of the load is .......... .
(b) The displacement of the load away from the equilibrium position is .......... .
(c) The velocity of the load is .......... .

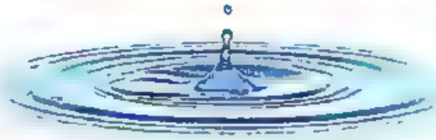
**What** do you think happens when you beat a drum? And why?

Chapter 1

Lesson Two

# Wave Motion

## What happens when a stone is dropped in a still lake?



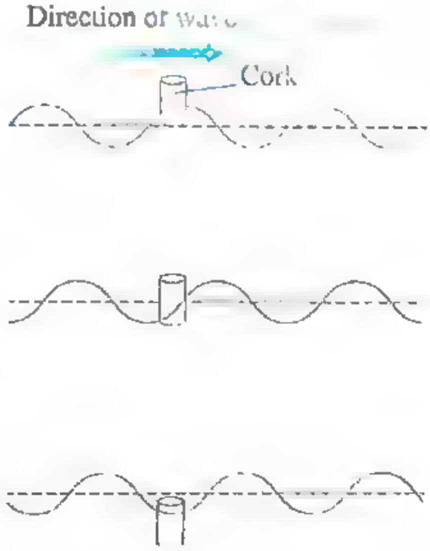
*Water waves*

**When a stone is dropped into water (as in the figure):**

- The collision of the stone with water becomes a source of disturbance.
- This disturbance propagates on the surface of water in the shape of uniform concentric circles, whose center is the position at which the stone falls.
- These circles transfer energy in the same direction of their propaga
- These circles are called water waves and their propagation represe

**From the previous, we can define the wave as follows:**

> **The wave :**
> It is a disturbance that propagates and transfers energy in the direction of propagation.




- When a wave propagates in a medium, the particles of the medium vibrate about their equilibrium positions without moving away from their equilibrium positions, this becomes clear when placing a piece of cork on the surface of water and causing a disturbance in the water, we find that the piece of cork moves up and down without moving from its position but the waves propagate in the water and thus energy is transmitted.

## Types of waves

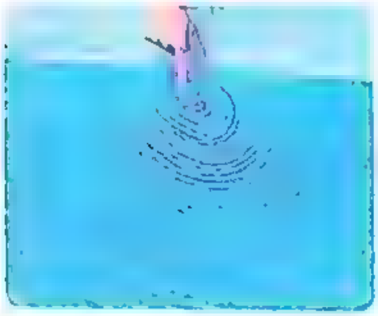
- Many forms of waves exist around us, some waves can be seen such as water waves, other waves cannot be seen but we can detect them such as radio and X-ray waves.

- Waves can be classified as the following:

| First | Second |
|---|---|
| **Mechanical** waves | **Electromagnetic** waves |

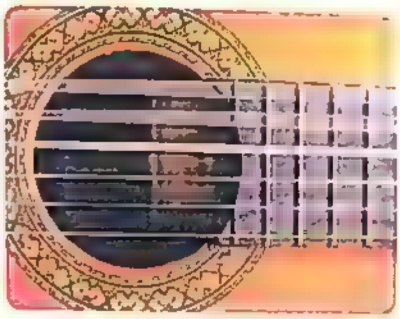
## First Mechanical waves

- **Source :** Mechanical waves are produced due to the vibration of a body in a medium, so the vibration (disturbance) propagates from the body through the medium.
- **Propagation :** They need a medium through which they can propagate.
- **Examples :**



Water waves

Sound waves

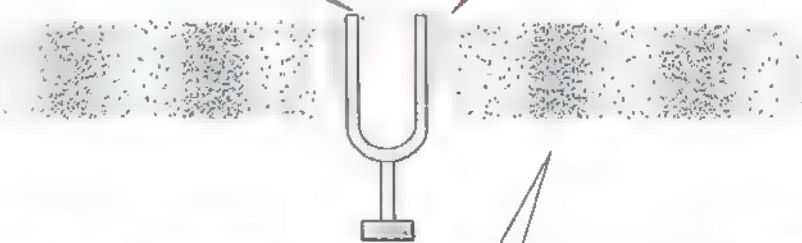


Waves that propagate in strings during their vibrations

### Conditions of obtaining mechanical waves

1. **The existence of a vibrating source:**
   **Like :** • Dropping a pebble in still water.
   • A vibrating string.
   • A vibrating pendulum.
   • The vibrating arms of a tuning fork.

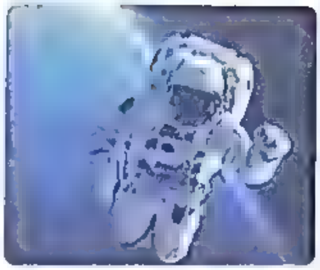
2. **The occurrence of a disturbance that transfers from the source to the medium:**
   Like the formed disturbances when the arms of a tuning fork gets vibrating.



3. **The existence of a medium to transmit the disturbance:**
   Mechanical waves (like sound waves) need a medium through which they can travel because the particles of the medium vibrate about their equilibrium positions without moving away from their positions to transfer the mechanical energy of the wave, so they can not propagate in space.

## Note :

- **Since sound is a mechanical wave, it cannot propagate in empty space, so:**
  - The sounds of cosmic explosions that happen in the outer space cannot be heard.
  - Astronauts use wireless devices to communicate in space.



## Types of mechanical waves

1. Transverse waves
2. Longitudinal waves

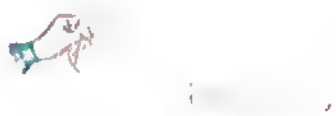
### 1 Transverse waves

To describe the nature of transverse waves, we carry out the following experiment

## Experiment

### Steps and observations:

1. Bring a long rope and fix its end to a vertical wall.
2. Hold the other end of the rope with your hand.
3. Move the end of the rope with your hand up and return it to the original position once.

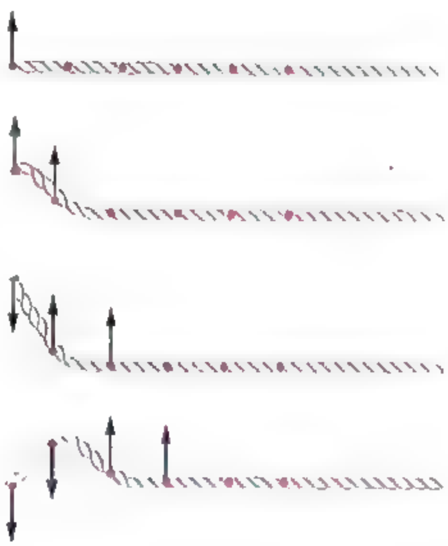


**Observation:** A pulse wave is generated through the rope (figure (1)).

**A pulse :**
It is a single disturbance in the form of a half wave.

**Explanation:**

- Energy gets transferred from the source to its adjacent part in the rope, hence this part moves upward.
- The tension force in the rope brings this part downwards, hence the energy gets transferred to next adjacent part, so this part moves upward and so on.
- The parts of the rope vibrate up and down successively.



4. Continue in moving the end of the rope up and down with a constant rate.

**Observation:** The end of the rope moves upwards and downwards in a simple harmonic motion that transfers along the rope as continuous wave pulses (transverse wave train) (figure (2)).

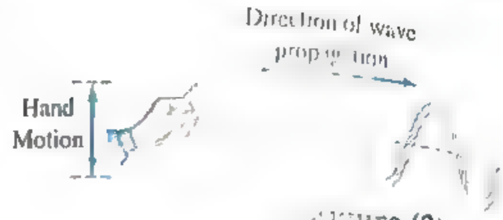



Figure (2)

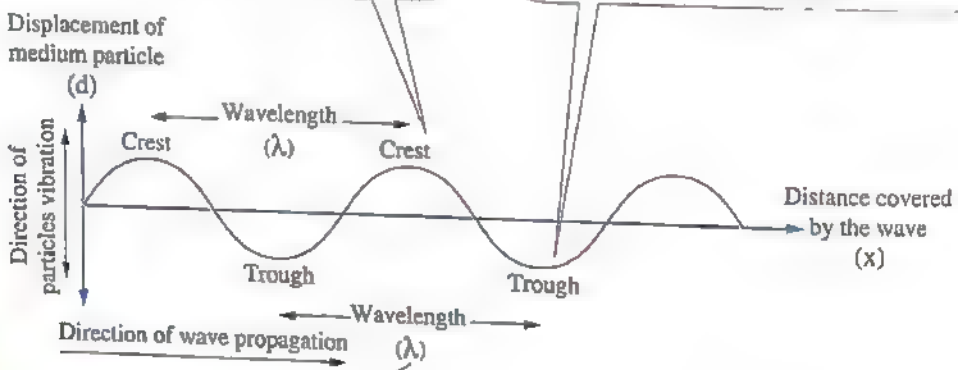
## Conclusion:

**(1) The direction of propagation of the wave through the rope is:**

- The direction of energy propagation.
- Perpendicular to the direction of motion (vibration) of the medium particles (the rope) about their equilibrium positions.

**A transverse wave :**
It is a wave in which the directions of medium particles vibrations about their equilibrium positions are perpendicular to the direction of wave propagation.

**(2) The transverse wave consists of crests and troughs as shown in the following figure:**

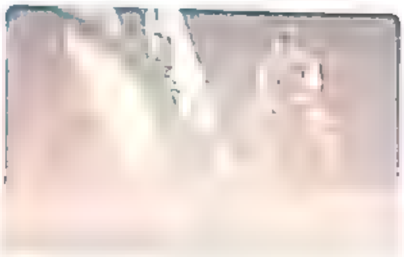



The distance between two successive crests or two successive troughs or any two successive points along the direction of propagation that are in the same phase is called **the wavelength of the transverse wave** (λ).

## Notice that:

A medium particle has the same phase at a definite position, when it passes through that position two successive times with the same velocity (including magnitude and direction).

*Examples of transverse waves :*



Battle rope waves

Water surface waves

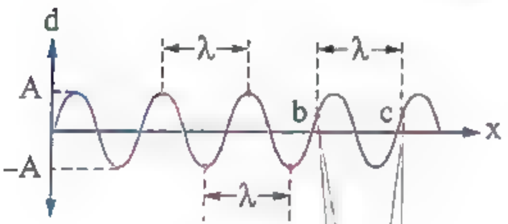
## Graphical representation of transverse waves

- **The motion of the particles of the medium in which the transverse wave propagates can be represented through the graphs of :**

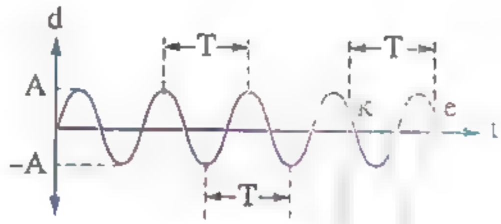
(1) **The displacement of the particles of the medium (d) versus the horizontal distance (x) covered by the wave at a certain instant.**

(2) **The displacement of one of the medium particles (d) versus time (t).**

**We get a sine curve**




The two points b,c have the same phase




The two points e,k have the same phase

**From the two graphs, we find**

$$\lambda = \frac{x\ \text{(Total distance)}}{N\ \text{(Number of waves)}}$$

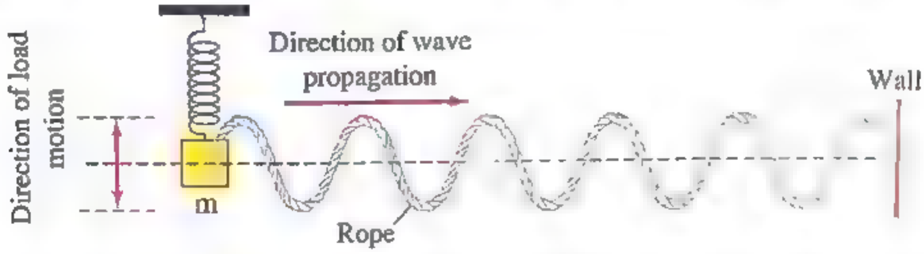
$$\upsilon = \frac{N\ \text{(Number of waves)}}{t\ \text{(Time in seconds)}} = \frac{1}{T}$$

- **From the previous, we can define the wave amplitude (A) as follows:**

**The wave amplitude (A) :**
It is the maximum displacement of the vibrating medium particles away from their equilibrium positions.

## Notes :

(1) Transverse waves can be obtained by using a load held to a ve[illegible] can vibrate up and down about its equilibrium position. The load is attached to a horizontal rope whose other end is fixed to a vertical wall, as the following figure:




In such case, the frequency of the transverse wave that propagates in the rope equals the frequency of the oscillatory motion of the load that is suspended to the spring.

(2) The amplitude of a transverse wave propagating in a stretched string depends on the work done by the vibrating source (the hand or a vibrating load) and that work gets transferred through the particles of the string in the form of:
- Potential energy as a tension in the rope.
- Kinetic energy as a vibration in the rope.

(3) The amplitude of the wave doesn't depend on any of the frequency or the wavelength of the wave.

### Enrichment Information

- **Travelling waves and standing waves can be distinguished from each other as follows:**

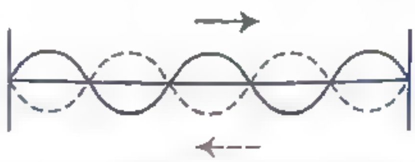
**Travelling wave**

The wave that propagates in one direction continuously moving away from its source.

*A travelling wave in a rope*

**Standing wave**

The wave that results from the overlap of waves that get reflected repetitively between two points.



*A standing wave on a string stretched between two clamps*

### Example 1

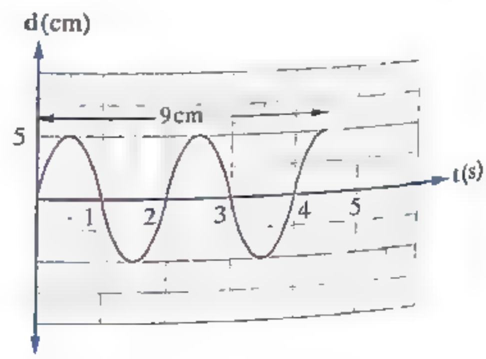
***The opposite graph represents a transverse wave, calculate:***

(a) The amplitude.

(b) The frequency.

(c) The periodic time.

(d) The wavelength.



## Solution

(a) A = 5 cm

(b) $\nu = \frac{N}{t} = \frac{2.25}{4.5} = 0.5$ Hz

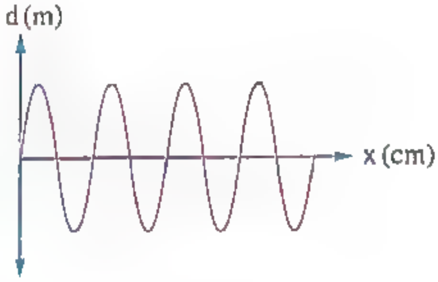
(c) T = 2 s

(d) $\lambda = \frac{x}{N} = \frac{9}{2.25} = 4$ cm

**What if** you are asked to determine the time interval between the passing of the second crest and the tenth crest by a definite point in the direction of wave propagation, what is your answer?

## Example 2

*The opposite graph represents the relation between the displacement (d) of the medium particles in which a transverse wave is travelling at a certain instant and the distance (x) travelled by the wave, if the distance between the first trough and the seventh crest is 5.5 cm, the wavelength of the wave equals ………… .*




ⓐ 5.5 cm ⓑ 5 cm ⓒ 1 cm ⓓ 0.5 cm

## Solution

x = 5.5 cm | | $\lambda$ = ?

The number of waves between the first trough and the seventh crest:

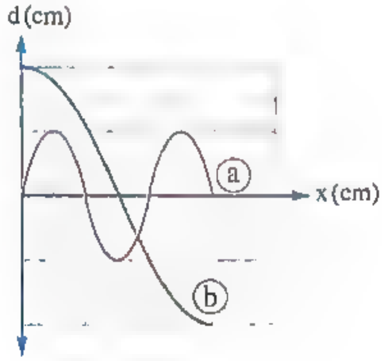
$N = (7-1) - \frac{1}{2} = 5.5$

$\lambda = \frac{x}{N} = \frac{5.5}{5.5} = 1$ cm

∴ The correct choice is ⓒ.

## Example 3

*The opposite graph represents the relation between the displacement (d) of the medium particles and the distance (x) travelled by two transverse waves ⓐ, ⓑ, so the ratio between their wavelengths $\left(\frac{\lambda_a}{\lambda_b}\right)$ equals ………… .*




ⓐ $\frac{3}{1}$ ⓑ $\frac{4}{3}$ ⓒ $\frac{1}{1}$ ⓓ $\frac{1}{3}$

## Solution

### Clue

*From the graph, we find that when the two waves cover the same horizontal distance, wave ⓐ makes 1.5 complete waves and wave ⓑ makes 0.5 complete wave.*

$\because \lambda = \frac{x}{N}$

$\therefore \frac{\lambda_a}{\lambda_b} = \frac{N_b}{N_a} = \frac{0.5}{1.5} = \frac{1}{3}$

$\therefore$ The correct choice is (d).

if you are asked to determine the ratio between the amplitudes of the two waves $\left(\frac{A_a}{A_b}\right)$, what is your answer?

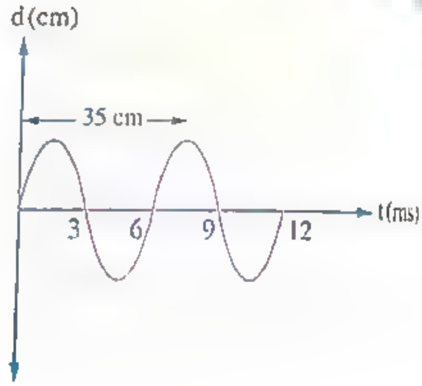
## Test yourself

1 * The opposite graph represents a transverse wave, calculate:

(a) The periodic time.

(b) The frequency.

(c) The wavelength.



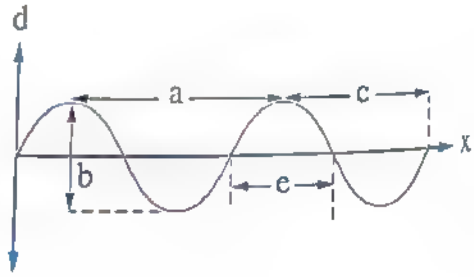

..............................................................................

..............................................................................

..............................................................................

2 Choose the correct answer :

The opposite graph represents the relation between the displacement (d) and the time (t) for a transverse wave, then:




(i) The wavelength for this wave is ............... .

ⓐ 2 c　ⓑ $\frac{1}{2}$ b

ⓒ 2 e　ⓓ 2 a

(ii) The amplitude of this wave is ............... .

ⓐ c　ⓑ e　ⓒ $\frac{1}{2}$ a　ⓓ $\frac{1}{2}$ b

(iii) Increasing the wavelength to the double leads to ............... .

ⓐ increasing distance c to four times its original value

ⓑ increasing distance a to the double

ⓒ decreasing distance b to its half

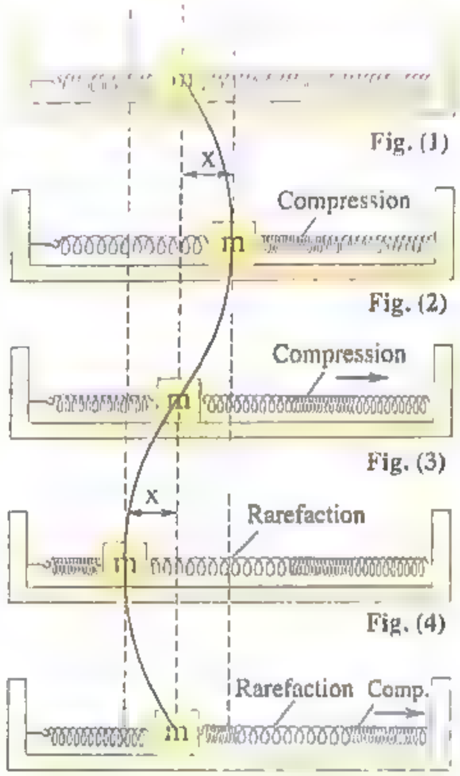
ⓓ unchanging distance e

## 2 Longitudinal waves

To describe the nature of longitudinal waves, we carry out the following experiment:

# Experiment

### Steps and observations:

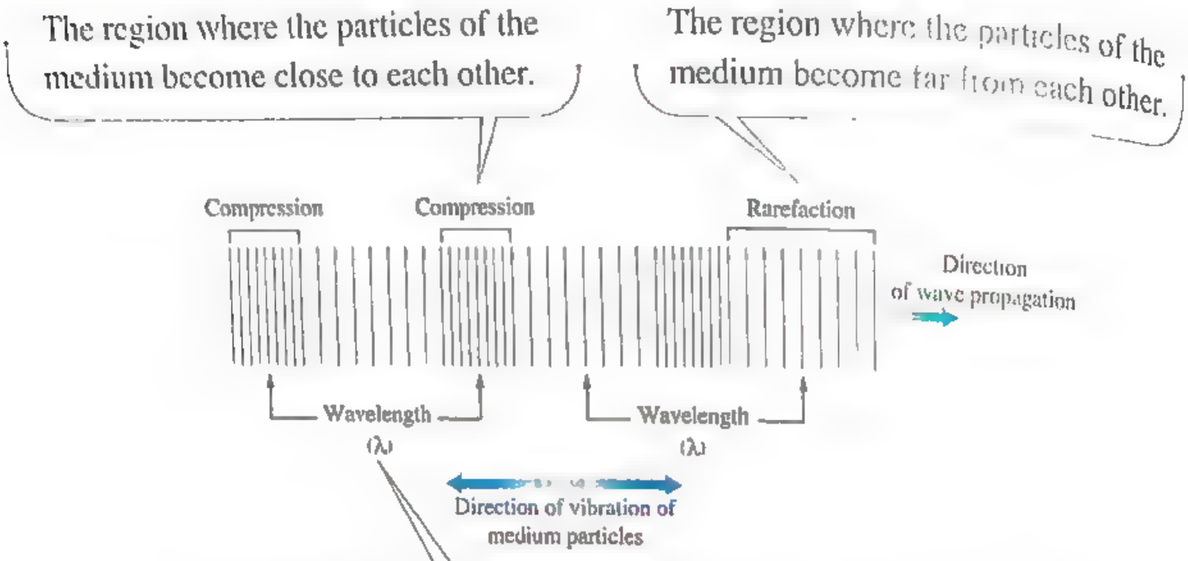



1. Put a load (m) on a smooth horizontal plane and attach the load between two springs, one of them is longer than the other and each of them is attached to a wall (figure 1).
2. Pull the load to a distance x to the right side.
3. A part of the spring which is adjacent to the load gets compressed at the right side forming a pulse of a compression (figure 2).
4. Leave the load free, so the load returns to its equilibrium position by the effect of the force generated in the spring at the left of the load, while the pulse of compression travels through the spring to the right of the load (figure 3).
5. The load exceeds the equilibrium position, moving to the left, creating a rarefaction in the spring towards the right (figure 4).
6. The motion of the load gets repeated to the right and the rarefaction pulse travels to the right (figure 5).

### Conclusion:

(1) During the vibration of the load, a wave propagates in the spring where the direction of vibration of the medium particles is along the same line of the wave propagation, such wave is called **longitudinal wave.**

2) The longitudinal wave consists of a group of compressions and rarefactions which transfer along the spring as shown in the following figure:

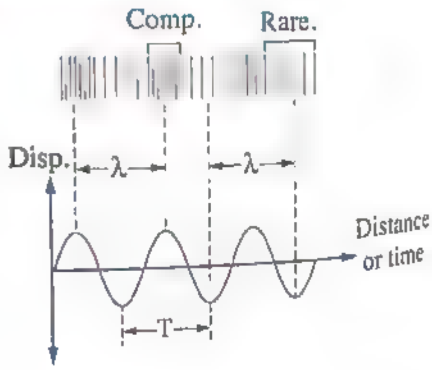



The distance between the centers of two successive compressions, two successive rarefactions or any two successive points along the direction of propagation that are in the same phase is called **the wavelength of the longitudinal wave.**

- ***Examples of longitudinal waves :*** - Sound waves in gases. - Waves inside water.

## Graphical representation of longitudinal waves

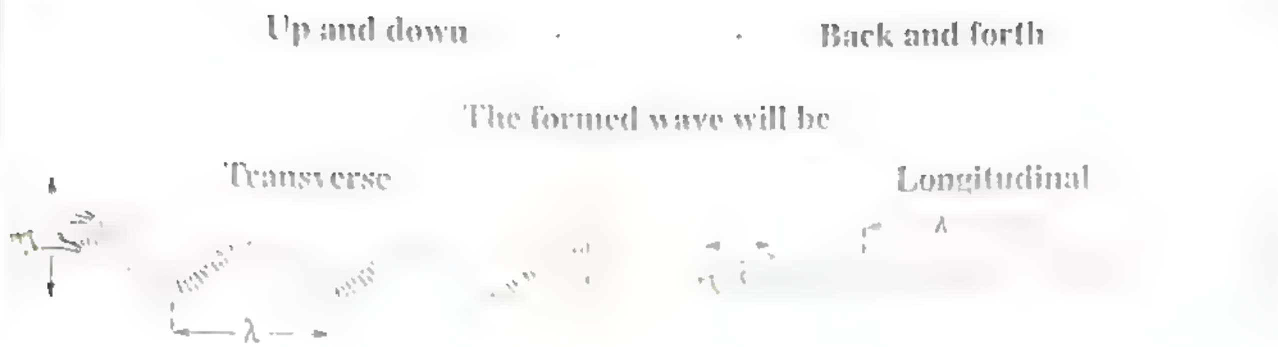
- When we plot the relation between the displacement of the medium particles and the distance travelled by the wave at a certain instant or between the displacement and the time for the motion of the medium particles in which the longitudinal wave propagates, we get a sine wave curve as shown in the opposite figure, hence all the concepts and the laws of the transverse wave are applicable to this curve.



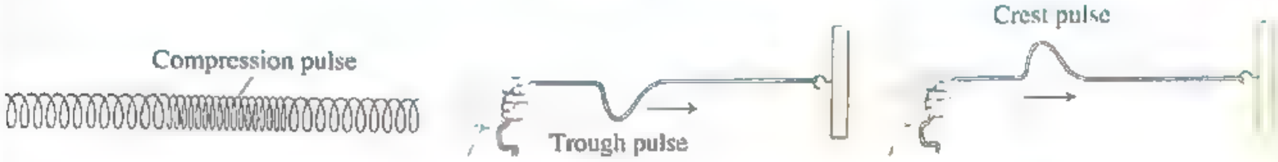

## Notes :

**(1) We can get transverse and longitudinal waves using a long spring coil:**

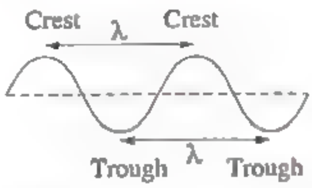
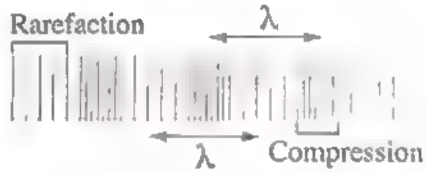
A transverse wave or a longitudinal wave can be produced in a long spring coil depending on the direction of the vibration of the wave source (a vibrating body) where the particles of the medium vibrate in the same way as the vibrating source, when fixing a spring coil horizontally from one of its ends while moving the other end of the coil:




(2) The pulse can be defined as a single disturbance forming a single half wave such as a single crest, a single trough, a single compression or a single rarefaction.

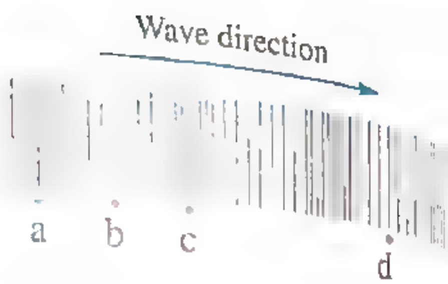



**From the previous, we can compare between the two types of mechanical waves (transverse and longitudinal) as follows:**

| | Transverse wave | Longitudinal wave |
|---|---|---|
| **Wave form** |  |  |
| **Direction of vibration of medium particles** | Perpendicular to the direction of wave propagation. | Along the line of wave propagation. |
| **Wavelength** | The distance between two successive crests or two successive troughs. | The distance between the centers of two successive compressions or the centers of two successive rarefactions. |
| **Examples** | • Propagating waves in strings.<br>• Waves on water surface. | • Sound waves in gases.<br>• Waves inside water. |

## Example

*The opposite figure represents a longitudinal wave. If the distance between the two points a and b is 1.7 m and the time taken by the wave to travel from c to d is 0.015 s, calculate:*




*(a)* The wavelength of the longitudinal wave.

*(b)* The frequency of the wave.

### Solution

$x_{ab} = 1.7$ m | $t_{cd} = 0.015$ s | $\lambda = ?$ | $\upsilon = ?$

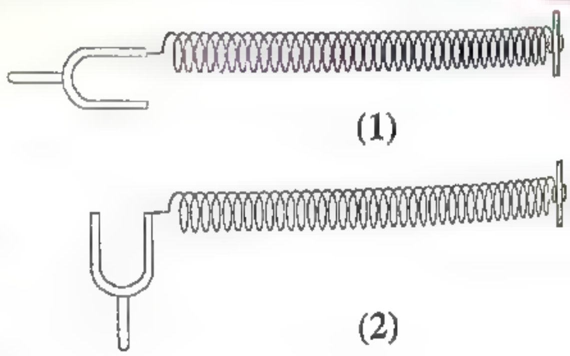
*(a)* $\lambda = \frac{x_{ab}}{N_{ab}} = \frac{1.7}{0.5} = 3.4$ m

*(b)* $\upsilon = \frac{N_{cd}}{t_{cd}} = \frac{1.5}{0.015} = 100$ Hz

What if you are asked to calculate the distance between the two points a, d and the time taken by the longitudinal wave to travel between them, what will be your answer?

## 2 Test yourself

1 The opposite figures show two tuning forks attached to two springs.



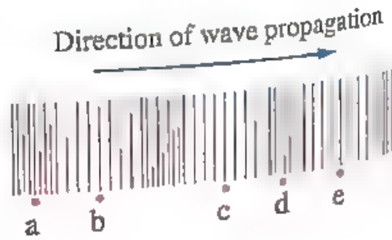

**What is the type of** wave that will be produced in each case when the forks vibrate?

.................................................................................................

.................................................................................................

2 Choose the correct answer :

The opposite figure represents a longitudinal wave, then the ratio between the two distances $\frac{X_{ac}}{X_{de}}$ is .................... .




ⓐ $\frac{1}{2}$ ⓑ $\frac{2}{1}$

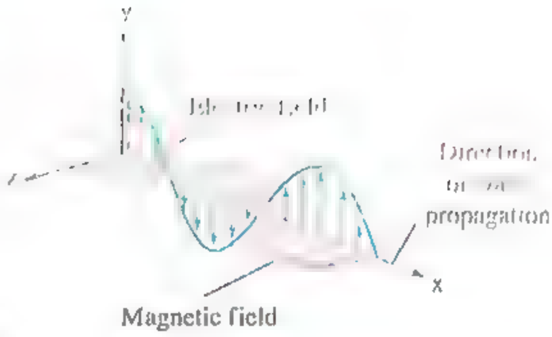
ⓒ $\frac{3}{2}$ ⓓ $\frac{3}{1}$

## Second

**Concept:**

**Electromagnetic waves:**

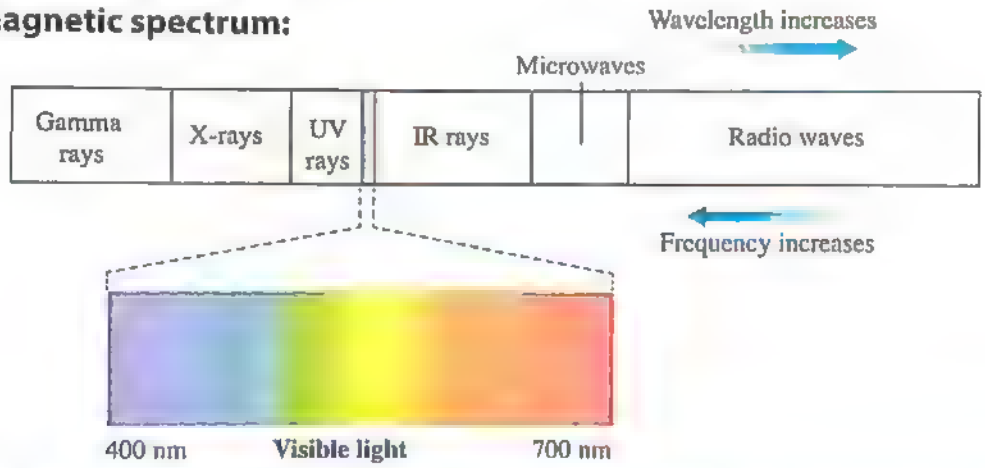
They are waves that originate from the vibration of electric and magnetic fields with the same frequency where both fields are in the same phase perpendicular to each other and to the direction of their propagation.




**Propagation:** They travel either in physical media or in empty space where their speed in space reaches its maximum constant value that equals $3 \times 10^8$ m/s.

**Types:** Transverse waves only.

**Electromagnetic spectrum:**




**From the previous, we can compare between mechanical and electromagnetic waves as follows:**

| | Mechanical waves | Electromagnetic waves |
|---|---|---|
| Concept | Waves originated from the vibration of medium particles either perpendicular to the direction of wave propagation or along the line of the wave propagation. | Waves originated from the vibration of electric and magnetic fields perpendicular to each other and to the direction of the wave propagation. |
| Propagation | They require a medium through which they can propagate. | They don't require a medium to propagate, so they can travel through empty space. |
| Types | Transverse and longitudinal waves | Transverse waves only |
| Examples | • Water waves. • Sound waves. • Propagating waves in strings. | • Radio waves. • Light waves. • X-ray waves. |

## Deducing the speed of propagation of th...

- If a wave has travelled a distance x through a time interval t, the speed of the wave (v) is calculated from the relation:

$v = \frac{x}{t}$

So, if the distance equals its wavelength ($\lambda$), then the wave takes a time equal to its periodic time (T).

$\therefore x = \lambda, t = T$

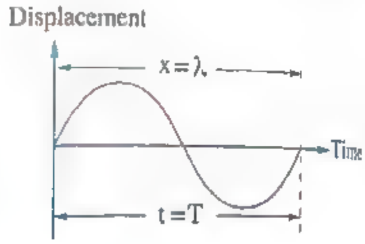
$\because \upsilon = \frac{1}{T}$

$\therefore v = \frac{\lambda}{T}$

$\therefore \boxed{v = \lambda \upsilon}$

**Wave sp...**

It is the distance travelled by the wave in one second in the direction of propagation.




This relation is applicable to all types of waves (mechanical or electromagnetic).

## The factors that affect the speed of a wave in a medi...

(1) The type of wave (mechanical or electromagnetic).

(2) Type of the medium material (solid, liquid, gas).

(3) The physical properties of the medium material (such as the density, elasticity, temperature) and it does not depend on the frequency of the wave, its wavelength or its amplitude.

## Note:

- **When applying the relation of $v = \lambda\upsilon$ on:**

**Two waves of the same type propagating in the same medium**

The speed of the two waves will be the same because the wave speed depends only on the medium type.

$$v_1 = v_2$$

$$\lambda_1 \upsilon_1 = \lambda_2 \upsilon_2$$

$$\therefore \boxed{\frac{\lambda_1}{\lambda_2} = \frac{\upsilon_2}{\upsilon_1}}$$

**A wave travelling from one medium to another**

The frequency of the wave remains constant because the wave frequency depends on the source frequency.

$$\upsilon_1 = \upsilon_2$$

$$\frac{v_1}{\lambda_1} = \frac{v_2}{\lambda_2}$$

$$\therefore \boxed{\frac{\lambda_1}{\lambda_2} = \frac{v_1}{v_2}}$$

**Where**

$\lambda_1$ and $\upsilon_1$ are the wavelength and the frequency of the first wave, $\lambda_2$ and $\upsilon_2$ are the wavelength and the frequency of the second wave.

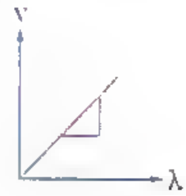
$\lambda_1$ and $v_1$ are the wavelength and the speed in the first medium, $\lambda_2$ and $v_2$ are the wavelength and the speed in the second medium.

*i.e.*

- The wavelength is inversely proportional to the frequency ($\upsilon$) at constant wave speed ($v$).
- The wavelength is directly proportional to the wave speed ($v$) at constant frequency ($\upsilon$).

**Graphical representation**


$$\text{Slope} = \frac{\Delta \upsilon}{\Delta(\frac{1}{\lambda})} = v$$




$$\text{Slope} = \frac{\Delta v}{\Delta \lambda} = \upsilon$$

**Example 1**

*Electromagnetic waves propagate in space at a speed $c = 3 \times 10^8$ m ... of an electromagnetic wave is 5000 Å, what is the frequency of this ...*
*(Given that: 1 Angstrom (Å) = $10^{-10}$ m)*

**Solution**

$c = 3 \times 10^8$ m/s | $\lambda = 5000$ Å | $\upsilon = ?$

$\lambda = 5000 \times 10^{-10} = 5 \times 10^{-7}$ m

$c = \lambda \upsilon$

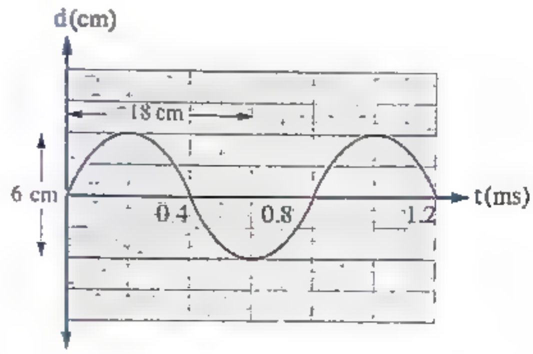
$3 \times 10^8 = 5 \times 10^{-7} \times \upsilon$

$\upsilon = \frac{3 \times 10^8}{5 \times 10^{-7}} = \mathbf{6 \times 10^{14}}$ **Hz**

**What if** you are asked to calculate the time taken by the light to reach the Earth from the Sun knowing that the average distance between the Sun and the Earth is $1.5 \times 10^8$ km, **what** will be your answer?

**Example 2**

*The opposite graph represents the relation between the displacement (d) of one of the particles of a medium and the time (t) for a longitudinal wave propagating in this medium, then the speed of propagation of this wave in the medium equals ............ .*




(a) 150 m/s
(b) 200 m/s
(c) 225 m/s
(d) 300 m/s

**Solution**

$$\lambda = \frac{X}{N} = \frac{18}{0.75} = 24 \text{ cm}$$

$$\upsilon = \frac{N}{t} = \frac{1.5}{1.2 \times 10^{-3}} = 1250 \text{ Hz}$$

$$v = \lambda\, \upsilon = 24 \times 10^{-2} \times 1250 = 300 \text{ m/s}$$

$\therefore$ **The correct choice is (d).**

**What if** you are asked to determine whether the ratio between the speed of wave propagation and the average speed of the vibration of one of the medium particles is greater than one, equal to one or less than one? **What** will be your answer?

**Example 3**

*A sound wave of wavelength $\lambda$ propagates in air with a speed of 330 m/s, if it has travelled to another medium in which its speed is 990 m/s, then its wavelength increases by ............ .*

(a) $\lambda$ (b) $2\lambda$ (c) $3\lambda$ (d) $4\lambda$

**Solution**

$v_1 = 330$ m/s | $v_2 = 990$ m/s | $\lambda_1 = \lambda$ | $\Delta\lambda = ?$

$\because v = \upsilon\, \lambda$

$$\therefore \frac{v_1}{v_2} = \frac{\lambda_1}{\lambda_2}$$

$$\frac{330}{990} = \frac{\lambda}{\lambda + \Delta\lambda}$$

$$3\lambda = \lambda + \Delta\lambda$$

$$\Delta\lambda = 2\lambda$$

$\therefore$ **The correct choice is (b).**

**What if** you are asked to determine if the frequency of the sound wave changes or not when it travels to the second medium. **What** will be your answer?

## Example 4

*Two tones, whose frequencies are 340 Hz and 212 Hz, [illegible] of one of them is longer than the other by 60 cm, then the [illegible] equals ............ .*

(a) 337.9 m/s (b) 430 m/s (c) 342.1 m/s (d) 343.2 m/s

### Solution

$\upsilon_1 = 340$ Hz | $\upsilon_2 = 212$ Hz | $\Delta\lambda = 60$ cm | $v = ?$

**Clue**

*When two waves have the same speed, their wavelengths and frequencies are inversely proportional, so the longer wavelength belongs to the smaller frequency.*

$\lambda_2 = \lambda_1 + \Delta\lambda = \lambda_1 + 0.6$

$\frac{\upsilon_1}{\upsilon_2} = \frac{\lambda_2}{\lambda_1}$ , $\frac{340}{212} = \frac{\lambda_1 + 0.6}{\lambda_1}$

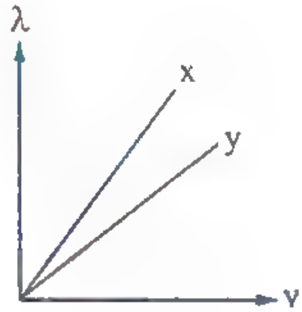
$340\,\lambda_1 = 212\,\lambda_1 + 127.2$ , $\lambda_1 = \frac{159}{160}$ m

$\therefore v = \upsilon_1\lambda_1 = \frac{159}{160} \times 340 = 337.9$ m/s

$\therefore$ The correct choice is (a).

## Example 5

*The opposite graph represents the relation between the wavelength (λ) for two waves (x, y) propagating in different media and the speed (v) of these two waves in each of these media, so which of the following relations is correct?*




(a) $T_x < T_y$ (b) $\upsilon_x > \upsilon_y$

(c) $T_x > T_y$ (d) $\upsilon_x = \upsilon_y$

### Solution

$v = \lambda\upsilon$

$\text{Slope} = \frac{\Delta\lambda}{\Delta v} = \frac{1}{\upsilon} = T$

$\because (\text{slope})_x > (\text{slope})_y$

$\therefore \upsilon_y > \upsilon_x$ , $T_x > T_y$

$\therefore$ The correct choice is (c).

**What if** you know that one of the two waves (x, y) is a red light wave and the other is a blue light wave, so **which** of them is the red light wave and which is the blue light wave?

## Test yourself

**Choose the correct answer:**

**1** ✱ If a sound wave has travelled from one medium to another so that the ratio between its wavelengths $\left(\frac{\lambda_1}{\lambda_2}\right)$ in the two media equals $\frac{2}{3}$, then the ratio between the speeds of sound in the two media $\left(\frac{v_1}{v_2}\right)$ equals .............. .

ⓐ $\frac{3}{4}$ ⓑ $\frac{4}{3}$ ⓒ $\frac{1}{1}$ ⓓ $\frac{2}{3}$

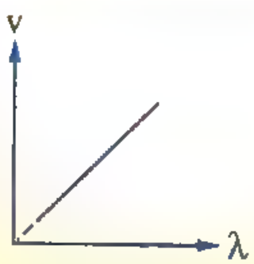
**2** ✱ If the ratio between the frequency of a man's sound and that of a girl's sound is $\frac{3}{4}$, then the ratio between the speeds of the sounds of the man and the girl in air equals .............. .

ⓐ $\frac{3}{4}$ ⓑ $\frac{4}{3}$ ⓒ $\frac{1}{1}$ ⓓ $\frac{16}{9}$

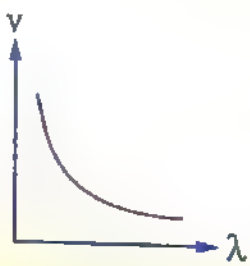
**3** A vibrating string produces a sound wave of frequency $\upsilon$, wavelength $\lambda$ and speed $v$, if the frequency of this string is increased, what will happen for each of the wave speed and the wavelength?

| | The wave speed | The wavelength of the wave |
|---|---|---|
| ⓐ | Increases | Increases |
| ⓑ | Increases | Decreases |
| ⓒ | Doesn't change | Increases |
| ⓓ | Doesn't change | Decreases |

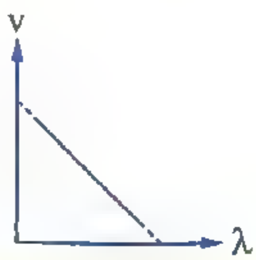
**4** Which of the following graphs represents the relation between the speed ($v$) of multiple sound waves propagating in air and the wavelength ($\lambda$) of these waves?



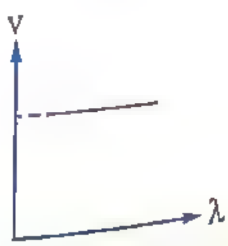
ⓐ



ⓑ



ⓒ



ⓓ

Chapter 1

Questions

Lesson

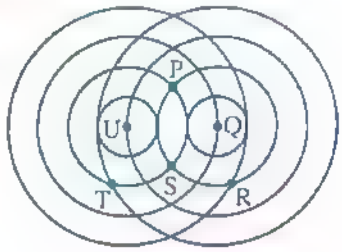
# Wave Motion

To watch videos of how to solve questions use the App

The questions signed by ✱ are answered

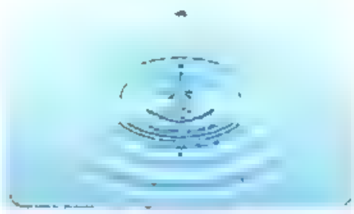
1. Waves transfer ......... in the direction of their propagation.
   (a) matter (b) particles (c) energy (d) water

2. ✱ Two waves interfere on the surface of water as shown in the opposite figure, which two points in the figure represent the sources of these waves?



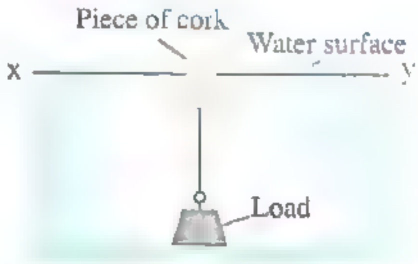

   (a) P, S (b) T, R
   (c) Q, T (d) U, Q

3. The opposite figure shows a wave propagating on the surface of a still lake, so this wave propagates in ......... .



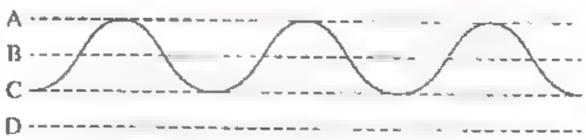
   (a) one direction with an increasing speed
   (b) two opposite directions with two different speeds
   (c) all directions with the same speed
   (d) all directions with increasing speed

4. A load is suspended to a piece of cork that floats on the surface of the water as shown in the figure, when a wave passes on the surface of water in the direction from x to y, in which direction does the piece of cork move?




   (a) Right and left. (b) Up and down.
   (c) From x to y. (d) From y to x.

5. A train of waves passes on the water surface of a lake as shown in the opposite figure. What will be the level at which the surface of water settles after the waves finish passing?

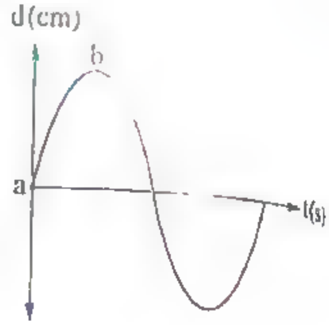



   (a) A (b) B (c) C (d) D

6. In the opposite wave, which of the points a, b, c, d have the same phase?


   (a) a, b, c (b) a, b (c) b, c (d) b, d

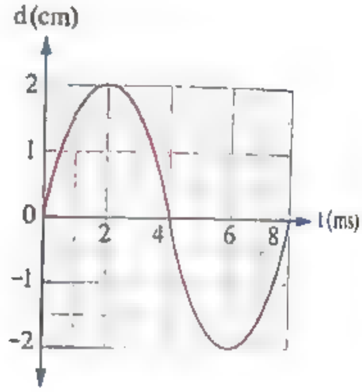
**7** * The opposite figure represents the relation between the vertical displacement (d) of one of the medium particles and the time (t) for a transverse wave of frequency that equals 50 Hz, then the time interval taken by the medium particle to move between the two points a and b is ............ .




ⓐ $\frac{2}{25}$ s ⓑ $\frac{1}{25}$ s

ⓒ $\frac{1}{50}$ s ⓓ $\frac{1}{200}$ s

**8** The opposite figure represents a transverse wave, so :




(i) The amplitude of this wave is ............ .

ⓐ 2 cm ⓑ 3 cm

ⓒ 4 cm ⓓ 6 cm

(ii) The frequency of this wave is ............ .

ⓐ 100 Hz ⓑ 125 Hz

ⓒ 250 Hz ⓓ 500 Hz

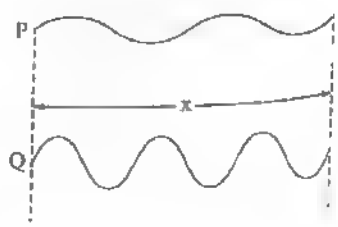
**9** * If the time interval between the pass of the first crest and the tenth crest by a point in the path of a wave motion is 0.2 s, then the frequency is ............ .

ⓐ 45 Hz ⓑ 50 Hz ⓒ 55 Hz ⓓ 60 Hz

**10** A girl dropped a stone in water pond and watched the formed waves. She found that 18 waves had collided with the edge during 10 s. If the distance between every two successive crests was 12 cm, so ............ , ............ .

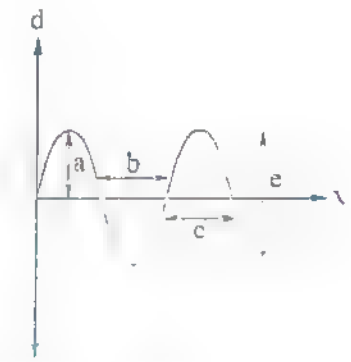
| | The wavelength (cm) | The frequency (Hz) |
|---|---|---|
| ⓐ | 24 | 1.8 |
| ⓑ | 24 | 0.6 |
| ⓒ | 12 | 1.8 |
| ⓓ | 12 | 0.6 |

**11** * The opposite two figures represent two water waves P and Q propagating on the surface of a lake for a distance x with the same speed, which of these two waves has the largest amplitude and which has the highest frequency?



| | The wave of the largest amplitude | The wave of the highest frequency |
|---|---|---|
| (a) | P | P |
| (b) | P | Q |
| (c) | Q | P |
| (d) | Q | Q |

12 ✻ The opposite graph represents the relation between the displacement (d) of the particles of a medium in which a transverse wave propagates with frequency υ, amplitude A and the distance (x) travelled by the wave, if :



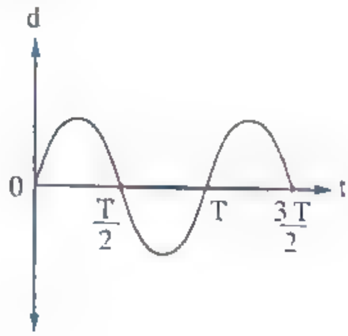

(i) The frequency of the wave is doubled at constant amplitude, then distance .......... .

(a) a increases to the double
(b) b increases to the double
(c) c decreases to its half
(d) e decreases to its half

(ii) The amplitude of the wave is doubled at constant frequency, then distance .......... .

(a) a decreases to its half
(b) b decreases to its half
(c) c increases to the double
(d) e increases to the double

13 A transverse wave propagates in a rope where the opposite graph of displacement (d) versus time (t) represents the motion of one of the rope particles, so what is the time required for this particle to return back to the same phase?

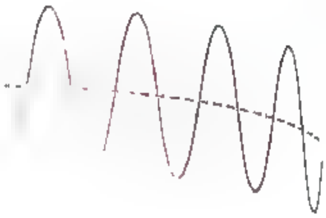



(a) $\frac{T}{2}$
(b) $\frac{T}{4}$
(c) T
(d) $\frac{3}{2}$ T

14 ✻ If the wavelength of a transverse wave is λ, then the distance between the first crest and the crest of order n equals .......... .

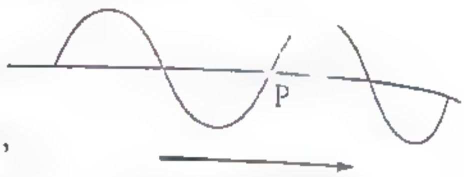
(a) $n\,\lambda$
(b) $(n+1)\,\lambda$
(c) $(n-1)\,\lambda$
(d) $(n-\frac{1}{2})\,\lambda$

15 In the opposite wave, if the distance between the first crest and the fifth trough is 140 cm, then the wavelength for this wave equals .......... .



(a) 10 cm (b) 20 cm
(c) 40 cm (d) 70 cm

16 The opposite figure shows a transverse wave propagating in a rope from left to right where in the shown instant the displacement at point P equals zero, so in which direction the point P moves at this instant?

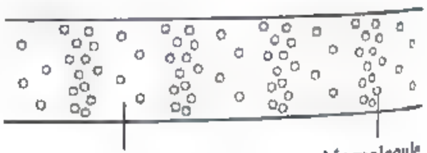



(a) Rightward. (b) Leftward.
(c) Upward. (d) Downward.

17 The following figures show four sources of waves, which of them causes the presence of longitudinal waves in its surrounding medium ?

| Light bulb | Horn speaker | TV remote control | Water waves |
|---|---|---|---|
| (a) | (b) | (c) | (d) |

18 The opposite figure represents a model of sound wave propagating through air inside a tube opened from both ends, how to describe region Q?

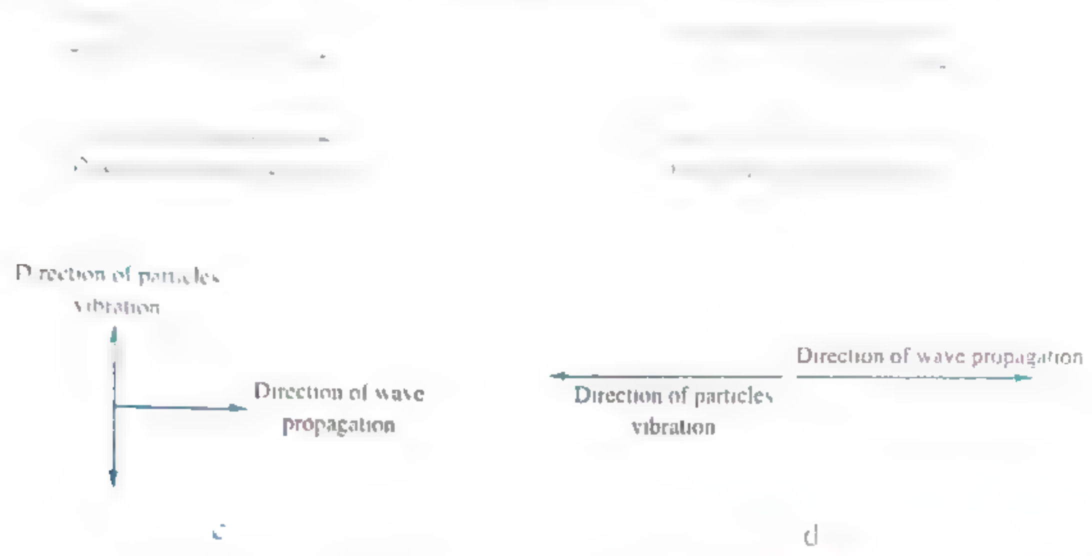



(a) A region of high density which is called compression.
(b) A region of low density which is called compression.
(c) A region of high density which is called rarefaction.
(d) A region of low density which is called rarefaction.

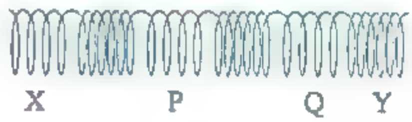
19 If the distance between two successive points having the same phase for a wave equals 50 cm, then the wavelength of this wave equals ............ .

(a) 0.125 m (b) 0.25 m (c) 0.5 m (d) 1 m

20 Which of the following figures represents the propagation of a longitudinal wave?




21 In the opposite figure, a longitudinal wave propagates in a spring, then the wavelength of this wave is the distance ............ .

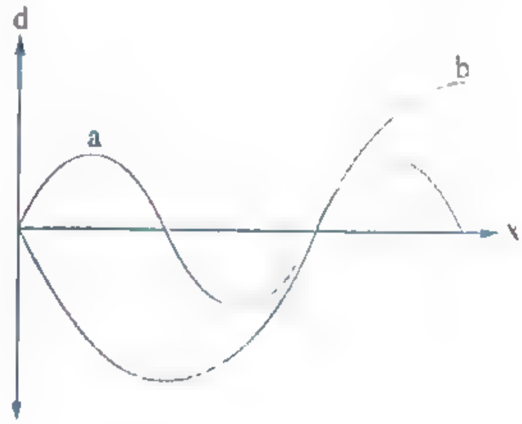



(a) PQ (b) 2 PQ (c) $\frac{XY}{2}$ (d) XY

22 When the frequency of a wave gets doubled, the periodic time of the wave gets ........

(a) halved (b) doubled (c) quadrupled (d) unchanged

23 The opposite graph represents the relation between the displacement (d) of the particles of a medium in which two sound waves propagate and the distance (x) travelled by the two waves so :




(i) The ratio between the frequencies of the two waves $\left(\frac{\upsilon_a}{\upsilon_b}\right)$ is ......... .

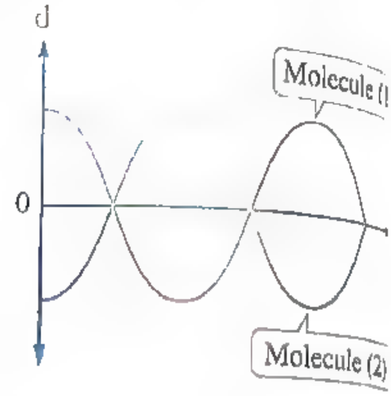
(a) $\frac{1}{1}$ (b) $\frac{2}{1}$

(c) $\frac{1}{2}$ (d) $\frac{1}{4}$

(ii) The ratio between the amplitudes of the two waves $\left(\frac{A_a}{A_b}\right)$ is ......... .

(a) $\frac{1}{1}$ (b) $\frac{2}{1}$ (c) $\frac{1}{2}$ (d) $\frac{4}{1}$

24. The opposite graph represents the displacements of two air molecules (1) and (2) that are separated by a distance of 10 cm along the direction of propagation of a sound wave versus time, so the wavelength of this wave could be equal to .......... .

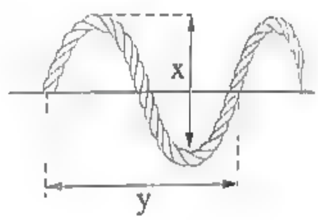



ⓐ 5 cm ⓑ 10 cm
ⓒ 20 cm ⓓ 40 cm

25. Sound travels in air as .............. .

ⓐ longitudinal waves ⓑ transverse waves
ⓒ longitudinal and transverse waves ⓓ electromagnetic waves

26. The opposite figure represents a wave propagating in a rope, then this wave is .......... .

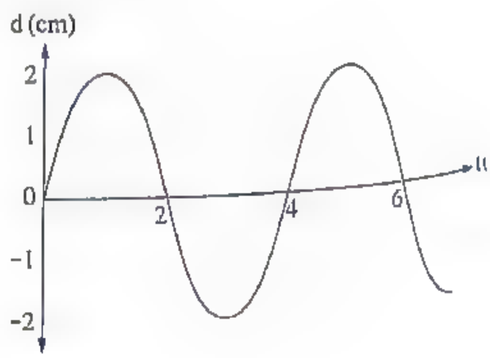



ⓐ a longitudinal wave of wavelength x
ⓑ a longitudinal wave of wavelength y
ⓒ a transverse wave of wavelength x
ⓓ a transverse wave of wavelength y

27. What is the characteristic that describes only the longitudinal waves and do not describe the transverse waves?

ⓐ They can be travelling waves.
ⓑ They require a medium in order to propagate.
ⓒ They transfer energy in the direction of their propagation.
ⓓ Their speed of propagation differs from medium to another.

28. The opposite graph represents the relation between the displacement (d) of one of the medium particles and the time (t), then the wave represented by the graph .......... .




ⓐ could be transverse or longitudinal of amplitude 2 cm
ⓑ is certainly not longitudinal and its amplitude is 2 cm
ⓒ could be transverse or longitudinal of amplitude 4 cm
ⓓ is certainly not transverse and its amplitude is 4 cm

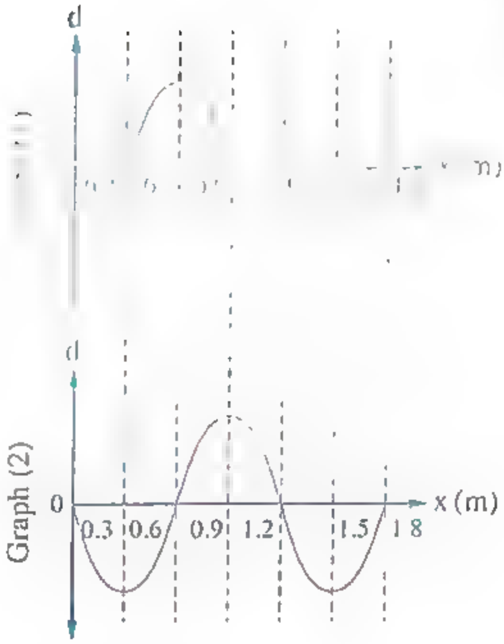
29 ✻ Graph (2) represents the position of a travelling wave in a string after 0.025 s from its position that is represented in graph (1), then the frequency of the wave equals ........ .

(a) 7.5 Hz

(b) 10 Hz

(c) 15 Hz

(d) 30 Hz




30 Which of the following statements is correct for all transverse waves?

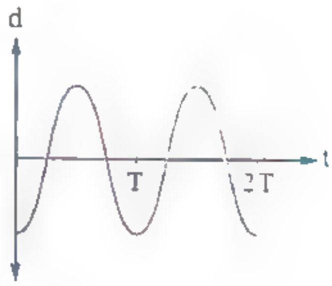
(a) They are electromagnetic waves.

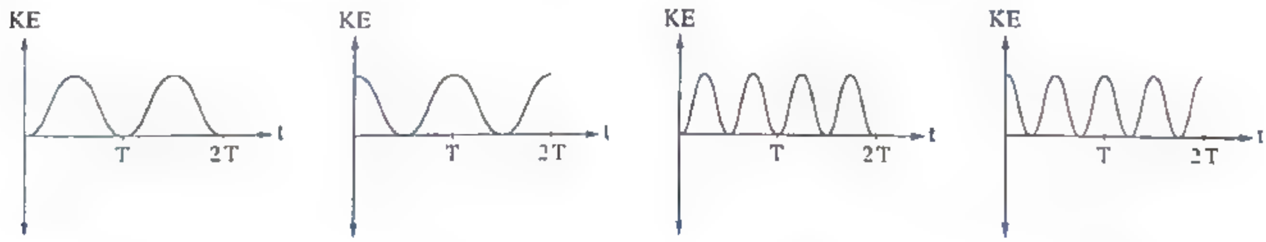
(b) Their speed in a medium equals the product of their frequency and wavelength.

(c) They can propagate through space.

(d) They cause vibrations of the medium atoms through which they propagate.

31 A wave propagates in a string and the opposite graph represents the relation between the displacement (d) of one of the string particles about its equilibrium position and the time (t), which of the following graphs represents the relation between the kinetic energy (KE) of this particle and the time (t)?




(a) (b) (c) (d)

32 When a pulse is made in a rope, the speed of the pulse along the rope ........ .

(a) remains constant

(b) decreases

(c) increases

(d) increases then decreases

33 ✳ A transverse wave propagates through a thin thread at speed 300 m/s. If the distance between two successive crests is 3 m, so the wave frequency equals ............ .

(a) 0.01 Hz (b) 100 Hz (c) 300 Hz (d) 900 Hz

34 ✳ A wave of frequency of 100 Hz is generated in a string, so it has a wavelength of 0.5 m, then :

(i) The wave speed through the string equals ............ .

(a) 25 m/s (b) 50 m/s (c) 100 m/s (d) 200 m/s

(ii) If the frequency increases to 300 Hz, the wavelength becomes ............ .

(a) 0.03 m (b) 0.17 m (c) 3 m (d) 6 m

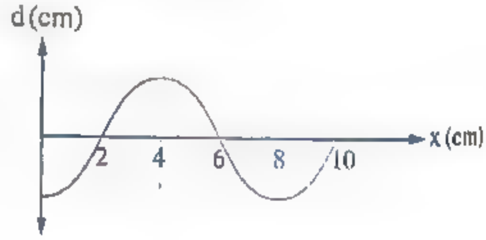
35 A girl stood on the beach to watch the waves. She observed that every two seconds four waves hit a rock in front of her where each wave has a length of 0.5 m, so the wave speed is ............ .

(a) 0.2 m/s (b) 0.25 m/s (c) 0.5 m/s (d) 1 m/s

36 If the frequency of a wave in a given medium decreases to its half, then ............ .

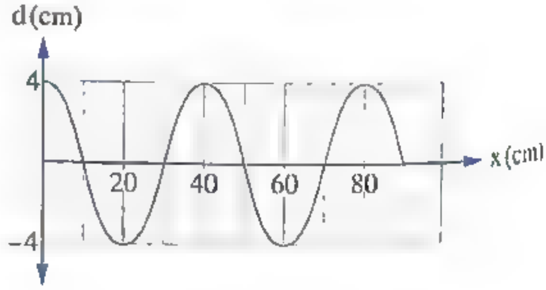
(a) its wavelength increases to the double (b) its wavelength decreases to the half
(c) its speed decreases to the half (d) its speed increases to the double

37 The opposite graph represents the relation between the displacement of medium particles (d) and the propagation distance (x) of a transverse wave at a certain instant. If the frequency of this wave is 80 Hz, its speed of propagation equals ............ .



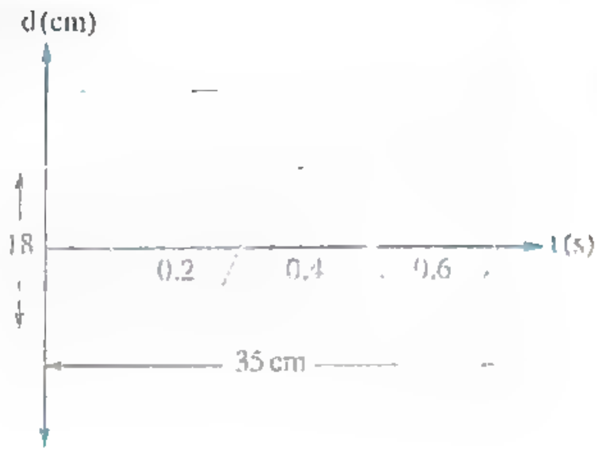

(a) 0.64 m/s (b) 0.32 m/s
(c) 6.4 m/s (d) 3.2 m/s

38 ✳ The opposite graph represents the relation between the displacement of the medium particles (d) through which a wave propagates and the horizontal propagation distance (x) of this wave, if one of the medium particles takes time t to have a displacement of 4 cm away from its equilibrium position, then the wave moves through the time t a distance of ............ .




(a) 10 cm (b) 20 cm (c) 40 cm (d) 80 cm

39 * The opposite graph represents the relation between the vertical displacement of one of the medium particles (d) and the time (t) for a wave, then:




(i) The amplitude of that wave is ............ .

ⓐ 9 cm ⓑ 17.5 cm
ⓒ 18 cm ⓓ 35 cm

(ii) The frequency of the wave is ............ .

ⓐ 1.7 Hz ⓑ 2.5 Hz
ⓒ 3.3 Hz ⓓ 5 Hz

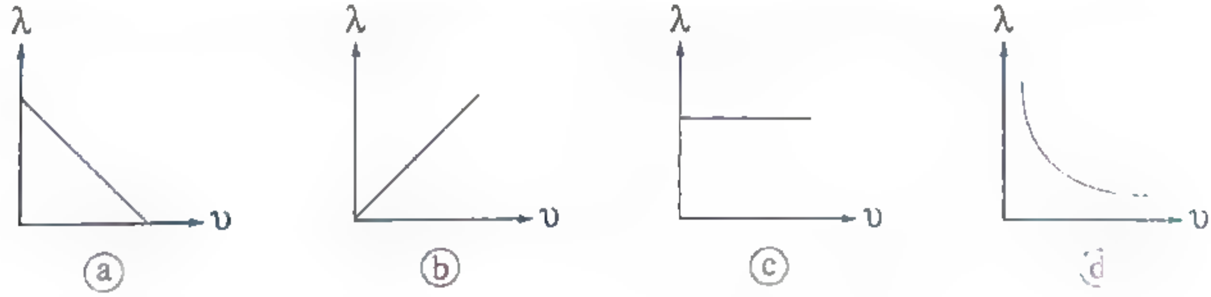
(iii) The wavelength of the wave is ............ .

ⓐ 0.05 cm ⓑ 17.5 cm ⓒ 20 cm ⓓ 35 cm

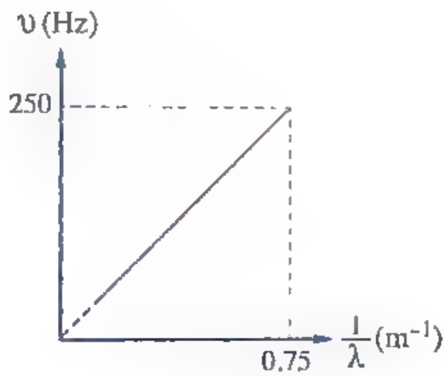
(iv) The propagation speed of the wave is ............ .

ⓐ 0.5 m/s ⓑ 0.6 m/s ⓒ 50 m/s ⓓ 60 m/s

40 Which of the following graphs represents the relation between the wavelength (λ) for multiple sound waves propagating in air and the frequency (υ) for each of these waves?

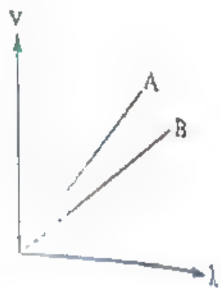



41 * A sound source produces tones with different frequencies propagating in air, the opposite graph represents the relation between the frequency (υ) and the reciprocal of wavelength $(\frac{1}{\lambda})$ for these waves, then the speed of the sound wave propagation through the medium almost equals ............ .




ⓐ 2 m/s ⓑ 50 m/s
ⓒ 254 m/s ⓓ 333 m/s

42 The opposite graph shows the relation between the speed (v) and the wavelength (λ) for two different waves of the same type (A and B) when they propagate through many different media, so ..........




ⓐ $\upsilon_A > \upsilon_B$ ⓑ $\upsilon_A < \upsilon_B$

ⓒ $T_A = T_B$ ⓓ $T_A > T_B$

43 Two laser rays, one of them is red and the other is green, propagate in space, so the two rays certainly have the same .......... .

ⓐ intensity ⓑ frequency ⓒ speed ⓓ wavelength

44 An electromagnetic wave of wavelength λ and frequency υ propagates in air with speed c, so which of the following choices represents the wavelength and the speed of another electromagnetic wave that has frequency $\frac{\upsilon}{2}$ and propagates in air?

| | The wavelength | The speed |
|---|---|---|
| ⓐ | $\frac{\lambda}{2}$ | $\frac{c}{2}$ |
| ⓑ | $\frac{\lambda}{2}$ | c |
| ⓒ | 2 λ | c |
| ⓓ | 2 λ | 2 c |

45 ✱ The human ear can hear frequencies between 20 Hz and $2 \times 10^4$ Hz, then the shortest and the longest wavelengths that can be heard by the human ear respectively are .......... .
(Given that: The speed of sound in air = 340 m/s)

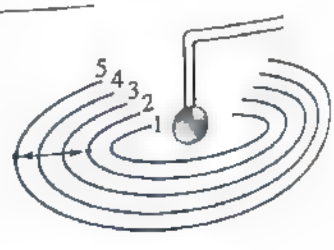
ⓐ 0.06 m, 59 m ⓑ 6800 m, $6.8 \times 10^6$ m

ⓒ 0.017 m, 17 m ⓓ 0.005 m, 0.05 m

46 ✱ If the number of waves that pass by a certain point every 5 s is 50 waves and the distance between the first and the fourth crests is 120 cm, then the speed of the wave propagation is .......... .

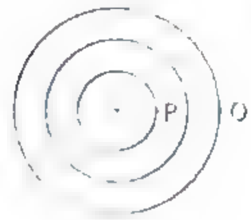
ⓐ 3 m/s ⓑ 4 m/s ⓒ 300 m/s ⓓ 400 m/s

47 ✱ The opposite figure represents a source vibrating with a frequency of 4 Hz producing waves that propagate on the surface of water with a speed of 0.4 m/s as concentric circular ripples around the source, given that each circle represents a crest, so the distance between the second and the fifth crest equals .......... .




ⓐ 0.1 m ⓑ 0.2 m ⓒ 0.3 m ⓓ 0.5 m

**48** A small stone has fallen into a pond of still water, circular waves are formed on the water surface as shown in the opposite figure where each circle represents a crest of a wave, if the speed of the water waves is v and its wavelength is λ, then the time taken by the disturbance to move from point P to point Q equals ..

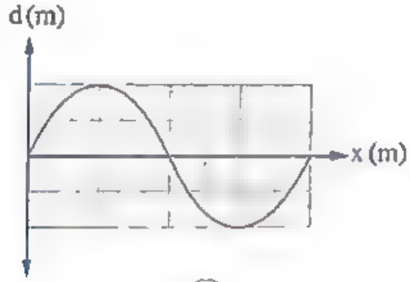



(a) $\frac{\lambda}{2v}$ (b) $\frac{\lambda}{v}$ (c) $\frac{3\lambda}{2v}$ (d) $2\lambda$

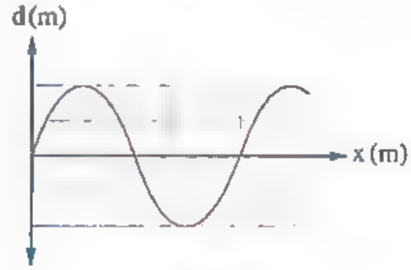
**49** ✻ If the speed of water waves that pass by a certain point is 1.5 m/s and there are 30 waves pass by this point in 1 s, then the number of waves in a distance of 60 m equals

(a) 3 waves (b) 40 waves (c) 400 waves (d) 1200 waves

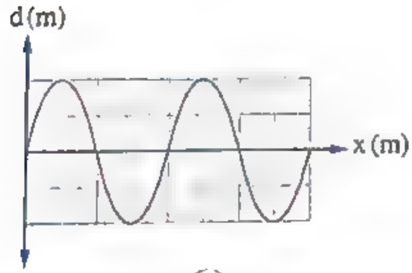
**50** ✻ A transverse wave is propagating in different media and the following graphs represent the relation between the vertical displacement (d) of the medium particles at a certain moment and the propagation distance (x) of the wave with the same scale in these media. In which medium does the wave have the highest speed?



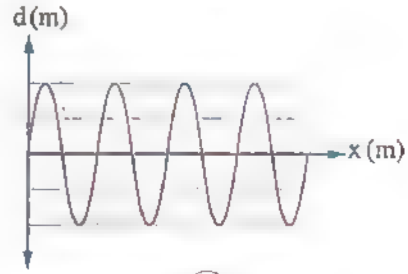

(a)




(b)

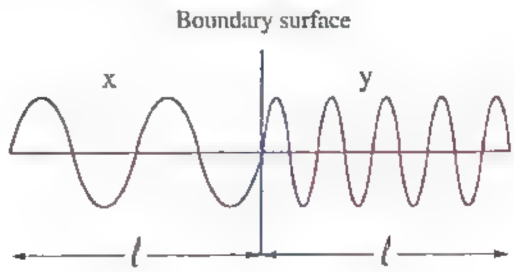



(c)




(d)

**51** ✻ The opposite figure shows a wave which is travelling through medium x then it moves to another medium y, so the ratio between the speed of the wave in medium x to its speed in medium y $\left(\frac{v_x}{v_y}\right)$ is ............ .




(a) $\frac{9}{4}$ (b) $\frac{4}{9}$ (c) $\frac{2}{1}$ (d) $\frac{1}{1}$

52 If the terminal of a spring is being moved to make a transverse wave of wavelength 30 cm and periodic time 0.1 s, then the terminal of the spring is being moved to make a longitudinal wave of periodic time 0.2 s which has the same speed as the transverse wave, so the wavelength of the longitudinal wave equals ............ .

(a) 7.5 cm (b) 15 cm (c) 30 cm (d) 60 cm

53 ✻ If the distance between the second crest and the seventh crest in a transverse wave is 20 m and the time interval between the pass of the first crest and the fifth crest by a certain point in the path of the wave is 0.1 s, then:

**(i)** The wavelength of the wave equals ............ .

(a) 0.2 m (b) 0.25 m (c) 4 m (d) 5 m

**(ii)** The speed of the wave propagation equals ............ .

(a) 250 m/s (b) 160 m/s (c) 10 m/s (d) 0.1 m/s

54 ✻ A stone was thrown into a lake, so 50 waves were formed after 5 seconds from the collision of the stone with the water, when the radius of the outer circle was 2 m, then:

**(i)** The wavelength of the wave is ............ .

(a) 0.04 m (b) 0.08 m (c) 25 m (d) 100 m

**(ii)** The frequency of the wave is ............ .

(a) 0.1 Hz (b) 10 Hz (c) 25 Hz (d) 250 Hz

**(iii)** The speed of the wave propagation is ............ .

(a) 2.5 m/s (b) 2 m/s (c) 1 m/s (d) 0.4 m/s

55 ✻ A train was at rest in a railway station when it blew a whistle of frequency 300 Hz. A man at distance 0.99 km from the train heard the sound 3 s later after being produced, then the wavelength of the sound equals ............ .

(a) 1.1 m (b) 0.91 m (c) 0.11 m (d) 0.09 m

56 ✻ A tuning fork of frequency 200 Hz was struck and put at one of the openings of a tube of length 8 m which was opened at both ends. If the beginning of the first wave reached the end of the tube when the sixth wave was about to enter the tube, the speed of sound in air is ............ .

(a) 360 m/s (b) 340 m/s (c) 330 m/s (d) 320 m/s

57. ✻ A wave of frequency $\upsilon_1$ and wavelength $\lambda_1$ propagates in a medium with speed $v_1$, if this wave travels from this medium to another medium where its speed becomes $\frac{2}{3}v_1$, then ............. .

(a) the frequency $\upsilon_1$ remains constant and the wavelength becomes $\frac{3}{2}\lambda_1$

(b) the frequency $\upsilon_1$ remains constant and the wavelength becomes $\frac{2}{3}\lambda_1$

(c) the wavelength $\lambda_1$ remains constant and the frequency becomes $\frac{3}{2}\upsilon_1$

(d) the wavelength $\lambda_1$ remains constant and the frequency becomes $\frac{2}{3}\upsilon_1$

58. ✻ Two sound waves a, b, whose frequencies are 512 Hz and 256 Hz respectively, propagate in a certain medium; so:

(i) The ratio between their speeds $\left(\frac{v_a}{v_b}\right)$ is ............. .

(a) $\frac{2}{1}$ (b) $\frac{1}{1}$ (c) $\frac{1}{2}$ (d) $\frac{3}{1}$

(ii) The ratio between their wavelengths $\left(\frac{\lambda_a}{\lambda_b}\right)$ is ............. .

(a) $\frac{2}{1}$ (b) $\frac{1}{2}$ (c) $\frac{3}{1}$ (d) $\frac{1}{3}$

59. ✻ A light ray falls on the separating surface between two transparent media. If the ratio between the speed of the light wave in the two media is $\left(\frac{v_1}{v_2}=\frac{2}{3}\right)$, then the ratio between the frequency of the light wave in the two media $\left(\frac{\upsilon_1}{\upsilon_2}\right)$ equals ............. .

(a) $\frac{1}{3}$ (b) $\frac{2}{3}$ (c) $\frac{1}{1}$ (d) $\frac{3}{2}$

60. A sound wave of frequency 512 Hz travels from air to water. If the speed of sound in air is 340 m/s and in water is 1360 m/s, so the frequency of the wave in water equals ...........

(a) 128 Hz (b) 256 Hz (c) 512 Hz (d) 2048 Hz

61. ✻ Electromagnetic waves were transmitted from a wireless transmission station towards a satellite with a speed of $3 \times 10^8$ m/s and after 0.03 s the station received the reflected waves from the satellite, hence the distance between the Earth and the satellite equals ............. .

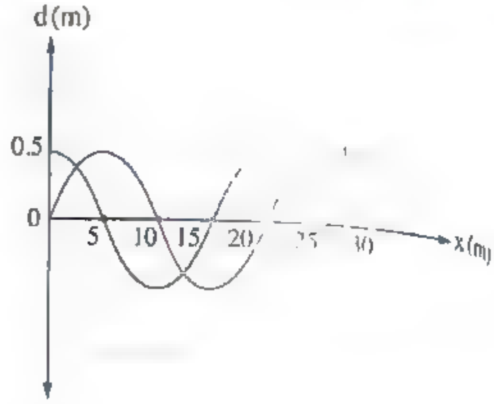
(a) $4.5 \times 10^6$ m

(b) $9 \times 10^6$ m

(c) $2 \times 10^{10}$ m

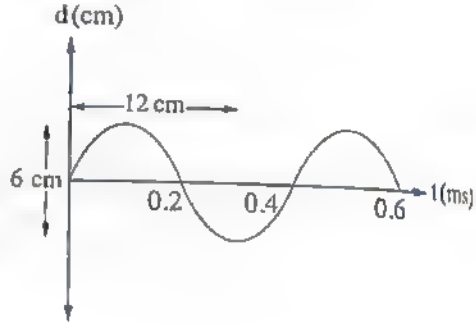
(d) $1 \times 10^{10}$ m

62 * In the opposite graph, curve A represents the relation between the vertical displacement (d) of the medium particles and the horizontal distance (x) covered by the wave at a certain instant while curve B represents the same relation for the same wave after passing 2 s, then the speed of wave propagation equals .......... .




ⓐ 1.25 m/s ⓑ 2.5 m/s ⓒ 5 m/s ⓓ 40 m/s

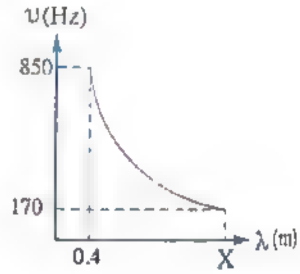
63 * The opposite graph represents the relation between the displacement (d) and the time (t) for a longitudinal wave propagating in a medium, then the ratio between the speed of the wave propagation and the average speed of the vibration of the medium particles is ......... .




ⓐ $\frac{4}{3}$ ⓑ $\frac{3}{4}$

ⓒ $\frac{2}{1}$ ⓓ $\frac{1}{2}$

64 * The opposite graph shows the relation between the frequency (υ) and the wavelength (λ) for the waves produced from several tuning forks that vibrate in air, so the value of X is ............ .




ⓐ 0.8 m ⓑ 1.2 m

ⓒ 1.6 m ⓓ 2 m

65 * The vertical distance between a crest and the consecutive trough in a transverse wave equals the horizontal distance between them. If the speed of the wave is 3.2 m/s and its frequency is 16 Hz, so its amplitude equals ............ .

ⓐ 0.5 m ⓑ 0.2 m ⓒ 0.1 m ⓓ 0.05 m

66 * Two tones have frequencies 680 Hz and 425 Hz in air. If the wavelength of one of them is greater than the wavelength of the other wave by 30 cm, then the speed of sound in air equals ............ .

ⓐ 320 m/s ⓑ 330 m/s ⓒ 340 m/s ⓓ 544 m/s

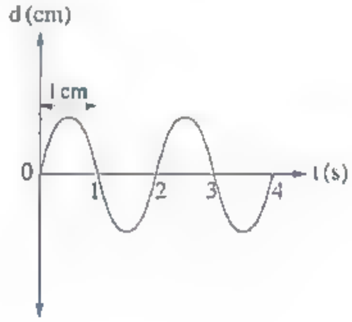
67 ✳ A stationary ship A sends two sound signals to another stationary ship B, one signal through air and other through water. If the signal that is transmitted in air reaches ship B after that transmitted in water by 6 s, then the distance between the two ships is .......... .
(Given that: The speed of sound in air is 340 m/s and in water is 1480 m/s)

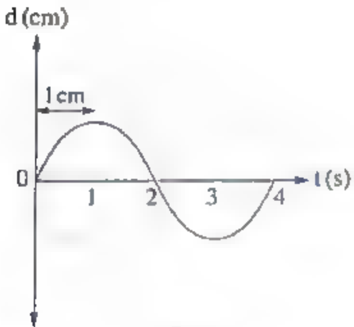
ⓐ $3.8 \times 10^{-4}$ km ⓑ 2.65 km ⓒ 1658.9 km ⓓ 264[illegible]

68 ✳ A boy heard the thunder 18.74998 s after seeing the lightning produced in a thunderstorm that was at a distance 6 km away, so the speed of sound in air was .......... .
(Given that : The speed of light in air = $3 \times 10^8$ m/s)

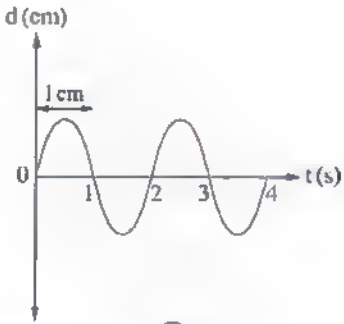
ⓐ 360 m/s ⓑ 340 m/s ⓒ 330 m/s ⓓ 320 m/s

69 ✳ The opposite graph represents a wave travelling through a medium with a speed v. If the wave has moved to another medium where its speed becomes 2 v, so the graph which represents the wave in the second medium will be .......... .




ⓐ

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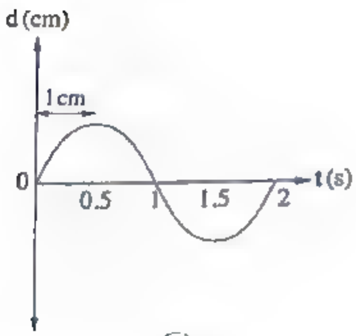


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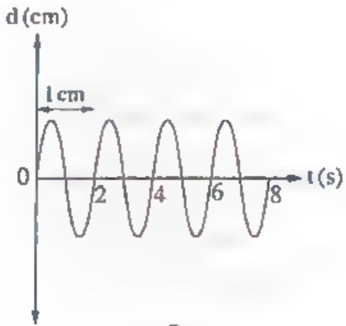



ⓓ

70 ✳ If the distance between the centers of a compression and its successive rarefaction in the path of a longitudinal wave is 0.15 m and the time taken by them to pass by a certain point in the path of the wave is $\frac{1}{150}$ s, then the speed of wave propagation equals .......... .

ⓐ 22.5 m/s ⓑ 45 m/s ⓒ 90 m/s ⓓ 100 m/s

## Second Essay questions

1. The opposite figure shows a pulse moving through a spring.

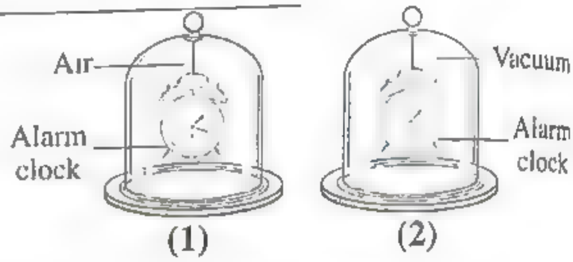
**Study the figure and answer the following questions:**

(a) **What** is the type of the produced mechanical wave in the spring?

(b) **What** is the direction of motion of the medium particles with respect to the direction of wave propagation?

2. In a rainy day, a boy noticed that he saw the lightning before hearing the thunder. **explain this observation.**

3. Two glass jars contain two alarm clocks. If one of them contains air and the other is evacuated from air, **which** of the two alarms can be heard? **And why?**



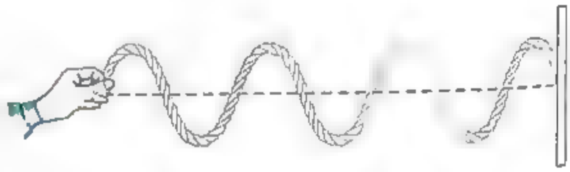

4. **Explain the following statements:**

(1) Electromagnetic waves don't need a medium through which they can propagate.

(2) We see the light of the Sun and don't hear the sound of the explosions on its surface.

(3) Astronauts use wireless devices to communicate on Moon.

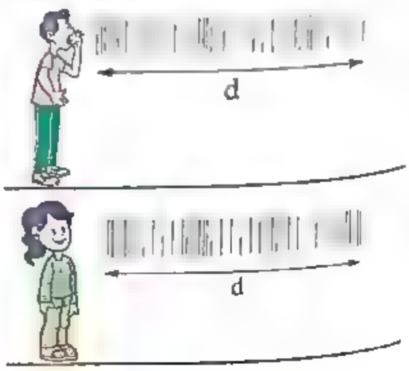
5. If a rope is fixed to the wall and its other terminal is being moved up and down so that a wave is produced in the rope as shown in the figure, so if you move your hand faster without changing the vertical displacement of your hand's motion or the tension force in the rope, **what happens for each of the following :**



(a) The amplitude? (b) The wavelength? (c) The frequency?

(d) The periodic time? (e) The wave speed?

6. The opposite figure shows the sound waves which are produced by a man and a girl :



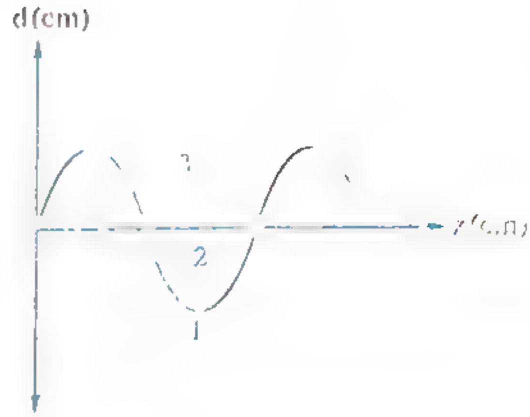

(a) **Which** of the two sound waves is travelling faster? **And why?**

(b) **Which** of the sound waves has higher frequency? **And why?**

**7** The opposite graph represents the relation between the vertical displacement (d) and the propagation distance (x) for three waves (1, 2 and 3) where each one of them propagates separately in a tight string stretched by a fixed tension force. Rank **these waves in a descending order according to:**

(a) Wavelength.

(b) Frequency.

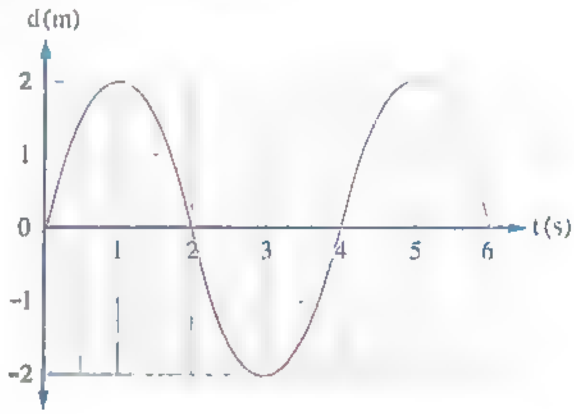



**8** The opposite graph shows the relation between the vertical displacement (d) and the time (t) of a wave motion which is formed in a rope:

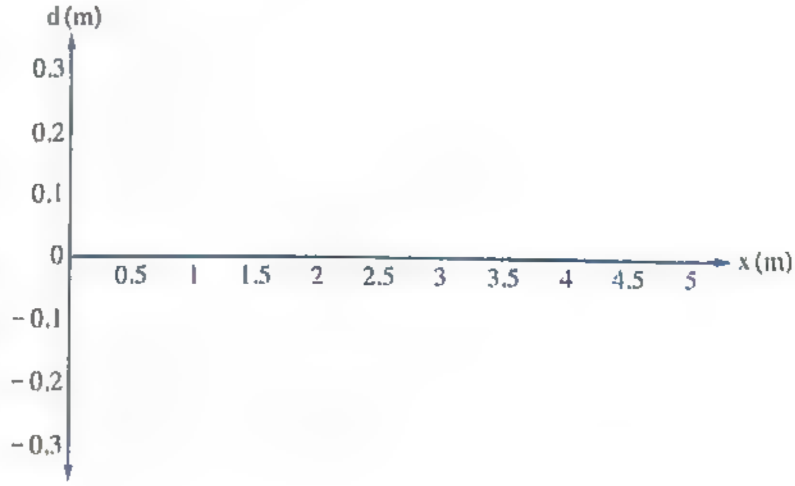
(a) **What** is the type of the formed wave in the rope?

(b) **Calculate** the frequency of the wave.

(c) **Draw** using the same scale the relation between the displacement (d) and the time (t) for a wave that has double the frequency and half the amplitude of this wave.

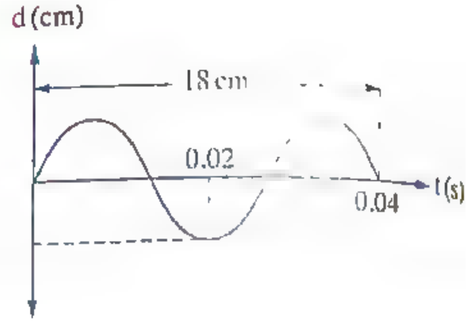



**9** A mechanical wave of wavelength 1 m and amplitude 0.2 m propagates in air for a distance 5 m , **draw** a graph representing the relation between the displacement (d) of the air particles and the distance (x) which the wave travels.



**First : Choose two correct answers in each of the following :**

**1** The opposite graph represents the relation between displacement (d) and time (t) for a transverse wave motion, which of the following choices characterize this wave motion?




(a) Its frequency is 50 Hz and its speed of propagation is 6 m/s.

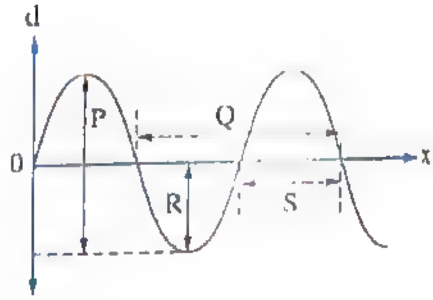
(b) Its frequency is 37.5 Hz and its speed of propagation is 4.5 m/s.

(c) Its periodic time is $\frac{1}{75}$ s and its speed of propagation is 4.5 m/s.

(d) Its periodic time is $\frac{2}{75}$ s and its wavelength is 18 cm.

(e) Its periodic time is $\frac{2}{75}$ s and its wavelength is 12 cm.

**2** The opposite graph represents the relation between the displacement (d) of the particles of a medium through which a wave propagates and the distance (x) travelled by the wave in its direction of propagation, which of the following sentences are correct for this wave?




(a) Distance P represents the wavelength.

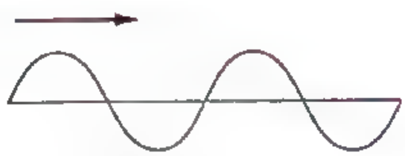
(b) The double of distance R represents the wavelength.

(c) The double of distance S represents the wavelength.

(d) Distance Q represents the double of the wave amplitude.

(e) Distance P represents the double of the wave amplitude.

**Second: Put in front of each of the following sentences the suitable number of the wave that represents it:**



Wave (1)

Wave (2)

(1) It represents a complete number of waves (Wave......)

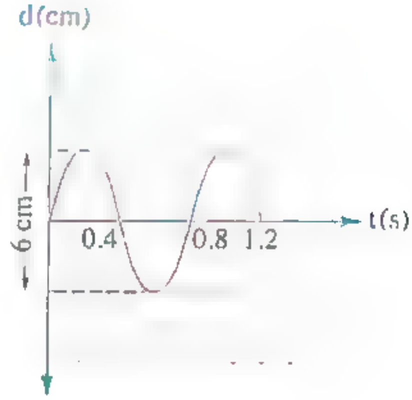
(2) The direction of medium particles vibrations for it is perpendicular on its direction of propagation (Wave......)

(3) The direction of medium particles vibrations for it is along its direction of propagation (Wave......)

(4) One example of it is the ultrasonic waves that propagate in air (Wave......)

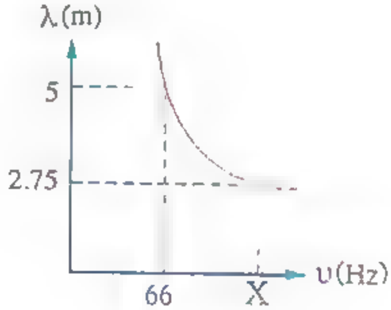
# Test on Chapter 1 Wave Motion

1. The opposite figure represents the (displacement - time) graph for a particle in a medium that transmits a transverse wave, so ........




| | Amplitude (A) cm | Frequency (υ) Hz |
|---|---|---|
| a | 6 | 2.5 |
| b | 6 | 0.4 |
| c | 3 | 1.25 |
| d | 3 | 0.8 |

2. The opposite graph shows the relation between the wavelength (λ) and the frequency (υ) of the sound waves produced by a number of tuning forks that vibrate in air, so the value of X is ............ .




a. 75 Hz

b. 120 Hz

c. 122 Hz

d. 150 Hz

3. The ratio between periodic time and frequency of an oscillating object equals $\frac{1}{289}$ $s^2$, so the number of oscillations that are produced in 20 s equals ............ oscillations.

a. 170 b. 289 c. 340 d. 510

4 A sound wave travelled from air to a liquid, hence its wavelength got changed from 0.5 m to 2.1 m, given that the speed of sound in air is 330 m/s, then the speed of sound in that liquid is ............ .

ⓐ 1420 m/s ⓑ 1386 m/s ⓒ 1320 m/s ⓓ 693 m/s

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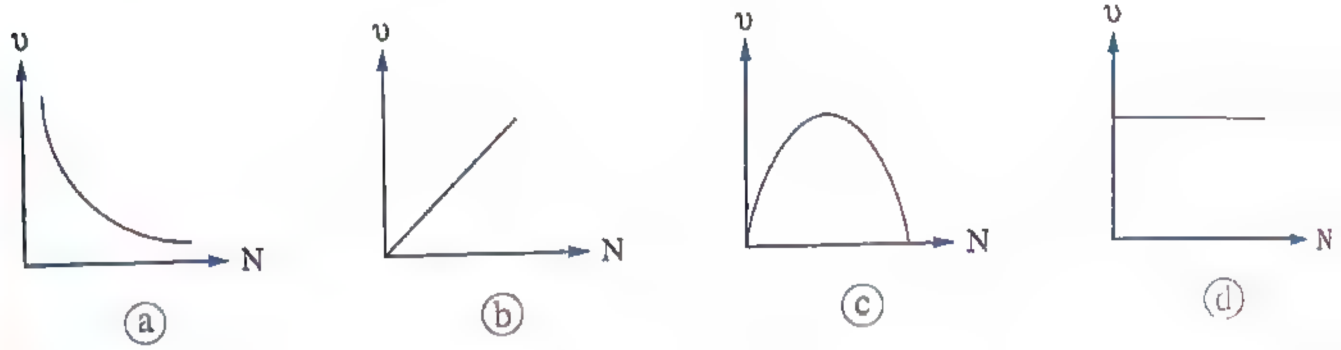
5 Which of the following graphs represents the relation between the frequency ($\upsilon$) for a simple pendulum and its number of oscillations (N)?

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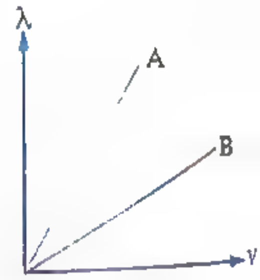
6 The opposite graph shows the relation between the wavelength ($\lambda$) and the speed (v) of two different waves (A and B) when they propagate in different media, so ............




ⓐ $T_A > T_B$

ⓑ $T_A < T_B$

ⓒ $\upsilon_A > \upsilon_B$

ⓓ $\upsilon_A = \upsilon_B$

---

7 When the terminal of a long spring is moved in such a way to make a longitudinal wave of wavelength 25 cm and periodic time 0.25 s, then it is moved to make a transverse wave of periodic time 0.1 s that travels at double the speed of the longitudinal wave, so the wavelength of the transverse wave is ............ .

ⓐ 10 cm ⓑ 12.5 cm

ⓒ 20 cm ⓓ 50 cm

8. A transverse wave of frequency 1.7 Hz travels at a speed of 3.4 m/s. If the vertical distance between a crest and a trough in it equals the horizontal distance between a crest and the successive trough, so the amplitude of the wave equals

(a) 0.25 m (b) 0.5 m (c) 0.7 ... (d) ...

9. Two sound waves of frequencies 300 Hz, 600 Hz travel in air, so the ratio between their speeds is ............ .

(a) $\frac{1}{2}$ (b) $\frac{1}{1}$ (c) $\frac{2}{1}$ (d) $\frac{1}{4}$

10. A pebble fell into the surface of still water, so 120 wave ripples are produced during half a minute. If the radius of the external circle is 3 m, the speed of propagation of the wave equals ............ .

(a) 0.01 m/s (b) 0.1 m/s (c) 0.5 m/s (d) 1 m/s

## Answer the following questions

11. The opposite figure shows a pendulum that is displaced away from its equilibrium position to point x then left to swing, **explain** the energy transformations just after leaving the pendulum directly till it reaches its equilibrium position.


..............................................................................................................

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12. **How does** the increase of frequency by 50 % affect the wavelength of a wave that travels in string stretched with a constant tension force?

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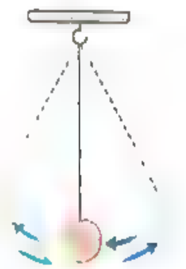
13. If elapsed time interval between the pass of the first crest and the eleventh crest by a point in the path of a wave motion is 0.02 s while the distance between the [illegible] crests is 45 m, **Calculate** the speed of propagation of this wave.

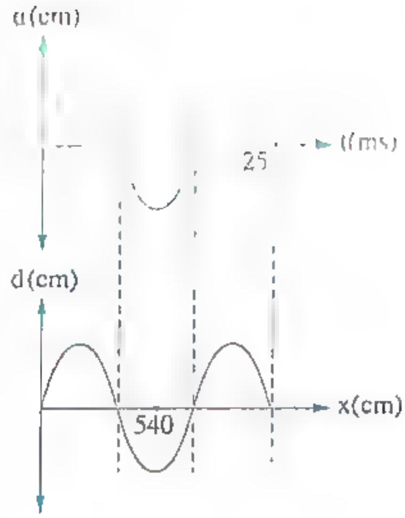
14. If a wave travelled from a medium to another so that its speed increased by 20 %, what was the percentage of change in its wavelength?

15. In the opposite figure, if the pendulum was making 30 complete oscillations per one minute, **calculate** the frequency and the periodic time.



16. A sound wave travels inside a glass tube from terminal x to terminal y as shown in the opposite diagram, **describe** how air molecules move inside the tube, **with explanation**.

17. The two opposite graphs show the relation between the displacement (d) of the particles of a medium and both of the time (t) and the distance (x) of propagation for the same wave motion. **Calculate** the speed of the wave.

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CHAPTER

# 2 Light

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- Deduce S
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- Identify internal

Lesson 1 [illegible]

Lesson 2 [illegible]

Lesson 3 [illegible]

Lesson 4 [illegible]

Lesson 5 Minimum Deviation [illegible]

- [illegible]
- Accumulative [illegible]

## Chapter objectives

By the end of this Chapter, the student will be able to:

- Mention the properties of light waves.
- Discover the two laws of light reflection and light refraction.
- Deduce Snell's law.
- Carry out an experiment to explain the light interference phenomenon and determine the wavelength of a monochromatic light.
- Carry out an experiment to explain the occurrence of diffraction of light.
- Compare between the reflection of light, the refraction of light, the diffraction of light and the interference of light.
- Identify the critical angle and the total internal reflection of light.
- Explain the working principle of optical fibers, the reflecting prism and the mirage phenomenon.
- Differentiate between the normal prism and the thin prism.
- Deduce the laws of a prism in the normal case and the special cases.
- Carry out an experiment to trace the path of a light ray through a triangular prism.
- Explain the dispersion of light by using a triangular prism.
- Deduce the dispersive power of a prism.
- Acquire the skills of solving problems by using the mathematical relations in this chapter.


Chapter 2

Lesson One

# Properties of Light

## (Propagation, Reflection and Refraction)

⊙ **Sun is the main original energy source for life on Earth and light is the main way of transferring this energy to Earth.**

## Wave nature of light

EKB

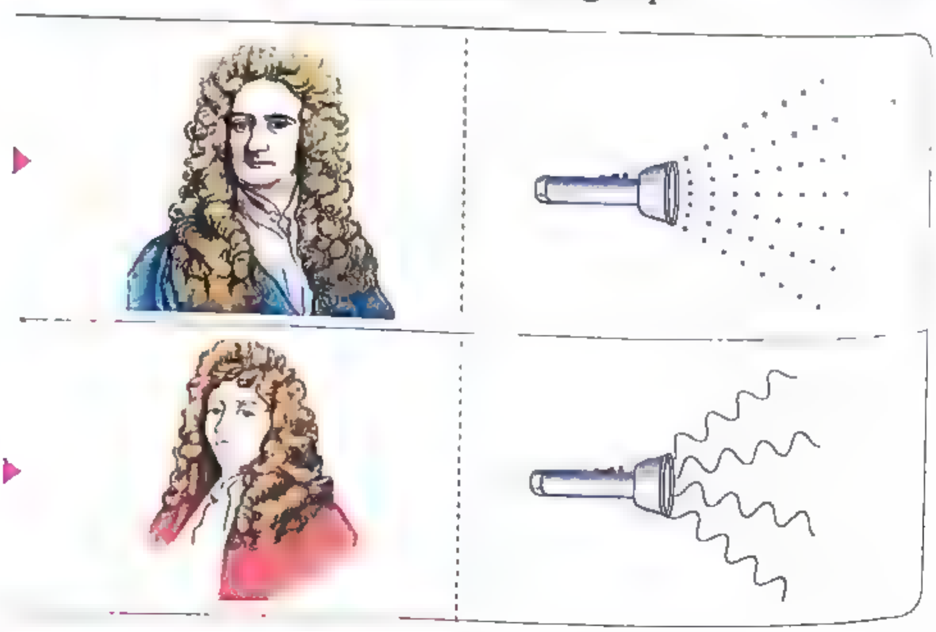
- In the study of the nature of light, physicists were divided into two groups:

**The first :**

They agree with **Isaac Newton's** idea which considers light as very tiny particles.

**The second :**

They agree with **Huygens'** idea which considers light as waves.



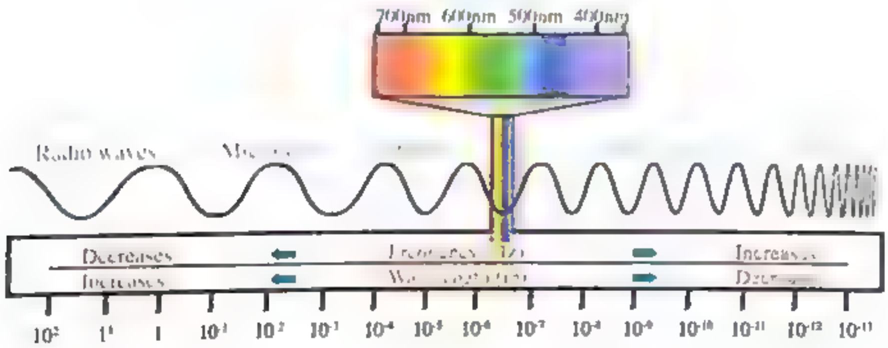
- **However, modern physics (quantum physics) has proven the principle of dual nature of light, which states that the electromagnetic radiation has:**

  1. **Wave nature:** They are transverse electromagnetic waves.
  2. **Particle na**[illegible] consist of energ[illegible] nature c[illegible] photons

- **Electromagnetic waves have an extensive range of frequencies and wavelengt**[illegible] **range is called:**

**The electromagnetic spectrum which includes**

- **Radio** waves
- **Microwaves**
- **Infrared** waves
- **Visible light** waves
- **Ultraviolet** waves
- **X-rays**
- **Gamma** rays



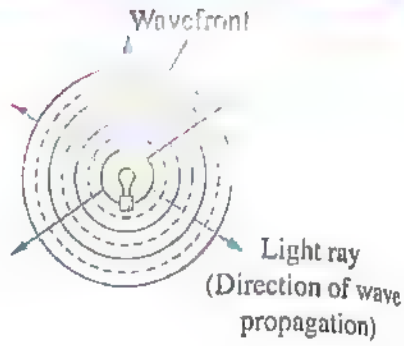

⊙ From the figure, it is clear that visible light is a limited part of the electromagnetic spectrum and in the following, we will study some of its properties:

**Some properties of visible light waves**

1. Propagation
2. Reflection
3. Refraction
4. Interference
5. Diffraction

## Light propagation

- Light that is originated from a point source propagates in a homogeneous medium in straight lines as concentric spheres of disturbances whose center is the light source and that can be illustrated through representing the wavefronts as shown in the opposite diagram:




**A wavefront** :
It is a surface in the path of wave motion on which the disturbances at every point have the same phase.

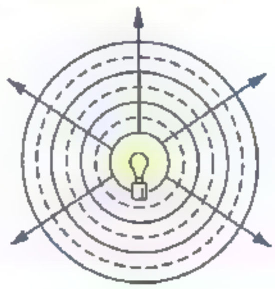
**Wavefronts can be of three types depending on the source of light as follows:**

**1 Plane wavefronts**

Obtained when waves are coming from:
- A laser light source.
- A very distant light source (like the Sun).

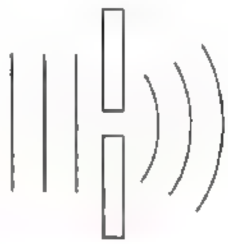

**2 Spherical wavefronts**

Obtained from a point source that sends out waves in three dimensions in a homogeneous medium as spherical wavefronts centered on the source.



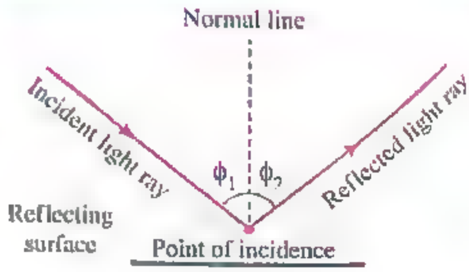
**3 Cylindrical wavefronts**

Obtained when waves are resulted from a longitudinal light source such as when light is passed through a fine rectangular slit.



## Second Light reflection

**Occurrence:**
When light waves fall in a medium on a reflecting surface, they bounce back in the same medium and this phenomenon is known as **light reflection**.



☆ **Light reflection, angle of incidence and angle of reflection can be defined as follows:**

**Light reflection**

It is the bouncing of light waves in the same medium when they encounter a reflecting surface.

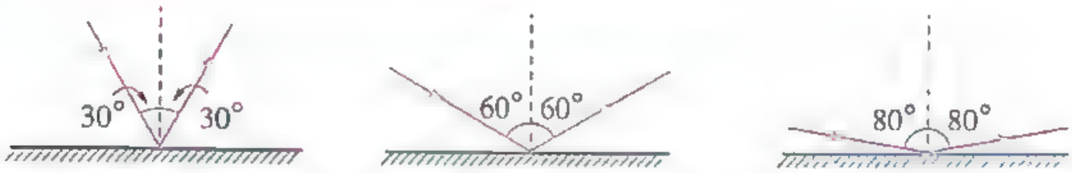
**The an[illegible]**

It is the angle between the incident light ray and the normal line on the reflecting surface at the point of incidence.

It is the angle [illegible] ray and the normal [illegible] reflecting surface at the point of incidence.

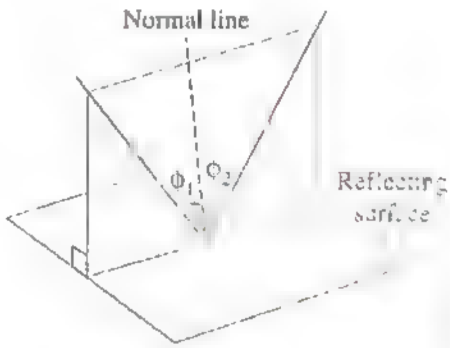
**[illegible]**

**The first law** Angle of incidence = Angle of reflection



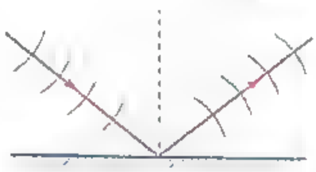

**The second law**

The incident light ray, the reflected light ray and the normal line at the point of incidence all lie in the same plane which is perpendicular to the reflecting surface.



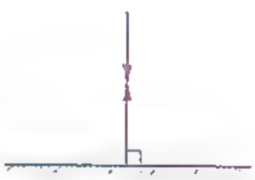

## Notes :

(1) Light reflection can be represented using wavefronts as shown in the opposite figure:

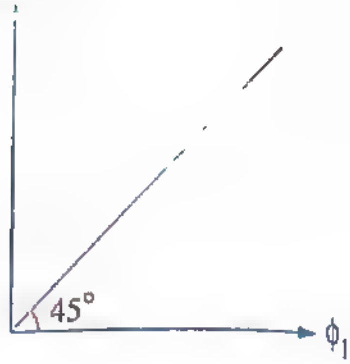


(2) **The light ray which falls perpendicular to a reflecting surface gets reflected on itself**

because the angle of incidence = The angle of reflection = Zero



(3) When plotting the relation between the angle of reflection ($\phi_2$) and the angle of incidence ($\phi_1$), we get a straight line and when the two axes have the same drawing scale, the straight line will make a 45° angle with the horizontal axis as in the opposite graph:




(4) It is easier to see your reflected image on the glass window of a lighted room at night when the outside is dark than seeing your reflected image at daytime:

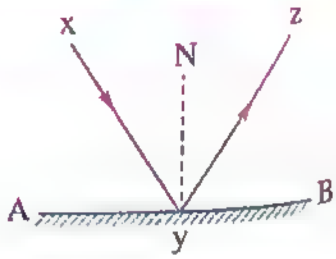
**Because**

| ⊙ **When outside of the room is dark:** | ⊙ **When outside of the room is lighted:** |
|---|---|
| The intensity of light passing from outside into the room is more lower than the reflected light from the inside, | The intensity of light passing from outside is larger than the reflected light intensity inside the room, |
| **So** | **So** |
| the person can see his image as a result of the light that is reflected on the glass inside the room. | it is difficult for the person to see his reflected image on the glass. |

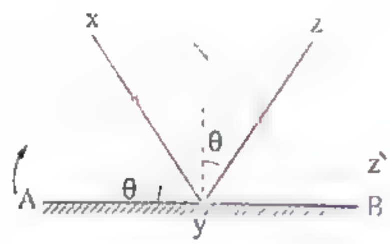
## The effect of rotating the reflecting surface and the incident light ray

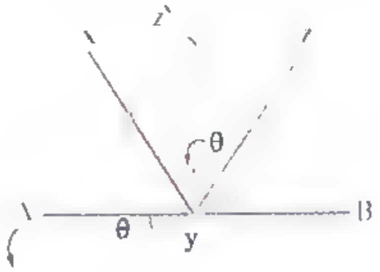
- When a light ray (xy) is incident on a reflecting surface (AB), the ray gets reflected as shown in the opposite figure such that:

Angle of incidence = Angle of reflection



**1** **When the reflecting surface rotates from plane AB with an angle θ to be in plane $\grave{A}\grave{B}$ without changing** the path of the incident ray (the normal line rotates with the same angle), that can be represented as follows:




**And we find that:**

(1) The angle of incidence and the angle of reflection

Each of them increases by a value θ | Each of them decreases by a value θ

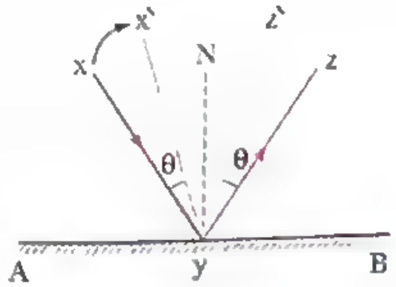
(2) **The angle between the incident ray and the reflected ray**

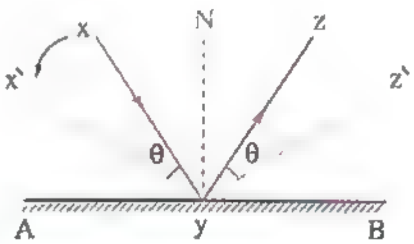
Increases by a value 2 θ | Decreases by a value 2 θ

(3) **The rotation of the reflected ray from its initial position**

Rotates by a value 2 θ in the same direction of mirror rotation

**2** **When the incident ray rotates with an angle θ to take the path of $\grave{x}y\grave{z}$ without changing the position of the reflecting surface,** that can be represented as follows:




**And we find that:**

(1) **The angle of incidence and the angle of reflection**

Each of them decreases by a value θ | Each of them increases by a value θ

(2) **The angle between the incident ray and the reflected ray**

Decreases by a value 2 θ | Increases by a value 2 θ

(3) **The angle between the reflected ray and the reflecting surface**

Increases by a value θ | Decreases by a value θ

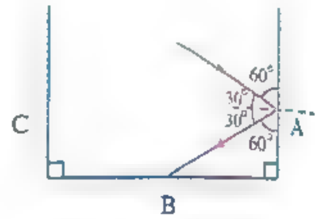
**Example 1**

*Three mirrors: A, B and C, are perpendicular to each other. If a light ray falls on mirror A as shown in the figure, trac the path of the light ray until its reflection at mirror C.*


## Solution

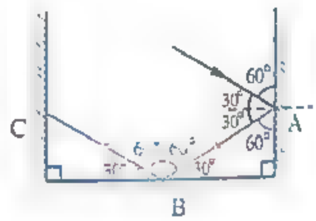
### Clue

*When the ray falls on mirror A such that the angle between the ray and the surface of the mirror is 60°, it means that the angle of incidence is 30° and as the angle of incidence = The angle of reflection, so the angle of reflection on mirror A is 30°, then the ray falls on mirror B.*



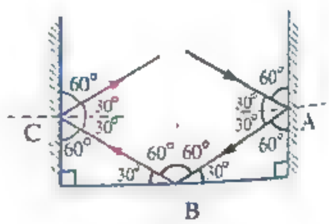

### Clue

*When the ray falls on mirror B, the angle between the incident ray and the surface of the mirror equals 30°, hence the angle of incidence equals 60°, so the ray gets reflected from mirror B with an angle of reflection 60° to fall on mirror C.*




### Clue

*When the ray falls on mirror C the angle between the incident ray and the surface of the mirror equals 60°, therefore the angle of incidence equals 30°, then the ray gets reflected at mirror C with an angle of reflection 30°.*

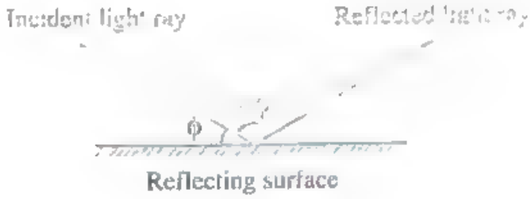



**What if** the angle between the two mirrors A, B becomes equal to 120° without changing the direction of the incident light ray, what will be the angle of reflection of the ray from mirror A?

## Example 2

*In the opposite figure, the angle of reflection equals ........*

ⓐ 30°  ⓑ 45°
ⓒ 60°  ⓓ 90°

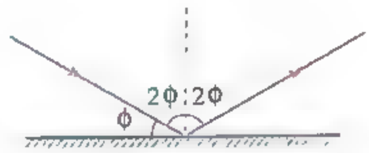



### Solution

∵ The angle of incidence = The angle of reflection

∴ The angle of reflection = 2 $\phi$

∵ The angle between the normal line and the reflecting surface = 90°




∴ $2\phi + \phi = 90°$

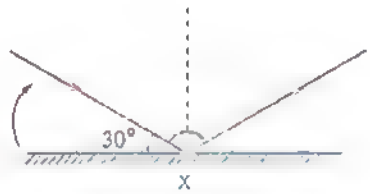
∴ $\phi = 30°$

∴ **The angle of reflection** = $2\phi = 2 \times 30 = 60°$

∴ **The correct choice is ⓒ.**

## Example 3

*If the mirror gets rotated about point x in the direction shown in the figure by an angle of 10°, the angle between the incident ray and the reflected ray becomes .......... .*



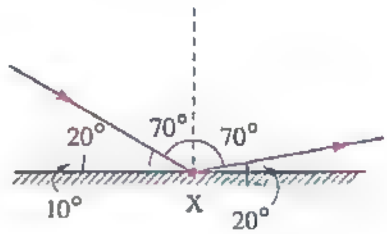

ⓐ 140°  ⓑ 135°
ⓒ 125°  ⓓ 115°

### Solution

- Before rotating the mirror:

∵ The angle of incidence ($\phi_1$) = The angle of reflection ($\grave{\phi}_1$)

∴ $\phi_1 = \grave{\phi}_1 = 90 - 30 = 60°$




- When rotating the mirror with 10°, both of the angle of incidence and the angle of reflection increases by the same value with which the mirror has rotated:

∴ $\phi_2 = \grave{\phi}_2 = \phi_1 + \theta_{rotation} = 60° + 10° = 70°$

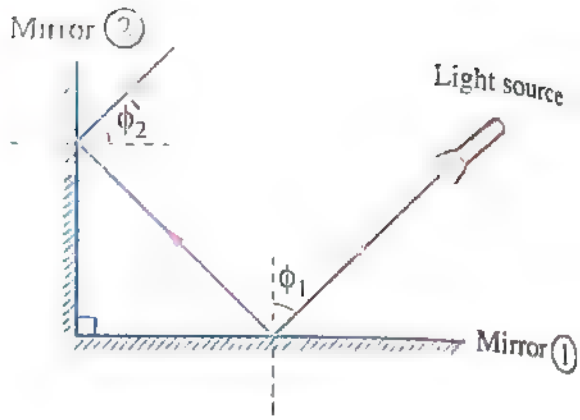
∴ **The angle between the incident ray and the reflected ray** = $\phi_2 + \grave{\phi}_2 = 70 + 70 = 140°$

∴ **The correct choice is ⓐ.**

**What if** you are asked to determine the direction of rotation of the reflected ray relative to the initial position, **what** will be your answer?

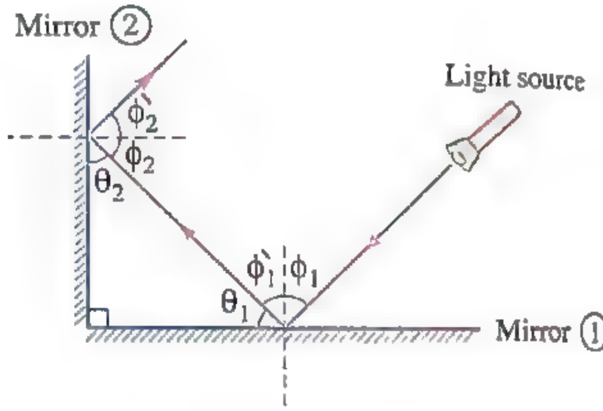
**Example** 4

*In the opposite figure, if the position of the light source is changed such that the angle of incidence ($\phi_1$) increases by 5°, the angle $\grave{\phi}_2$ will ..........*




(a) increase by 5°
(b) increase by 10°
(c) decrease by 5°
(d) decrease by 10°

**Solution**




$\because \phi_1 = \grave{\phi}_1$

$\therefore$ When $\phi_1$ increases by 5°, $\grave{\phi}_1$ increases by 5°

$\because \grave{\phi}_1 + \theta_1 = 90°$

$\therefore$ When $\grave{\phi}_1$ increases by 5°, $\theta_1$ decreases by 5°

$\because \theta_1 + \theta_2 = 90°$

$\therefore$ When $\theta_1$ decreases by 5°, $\theta_2$ increases by 5°

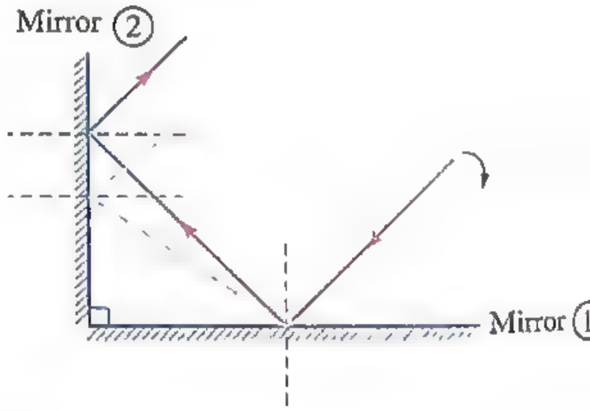
$\because \theta_2 + \phi_2 = 90°$

$\therefore$ When $\theta_2$ increases by 5°, $\phi_2$ decreases by 5°

$\because \phi_2 = \grave{\phi}_2$

$\therefore$ When $\phi_2$ decreases by 5°, $\grave{\phi}_2$ decreases by 5°

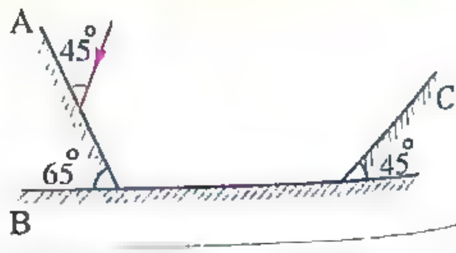
$\therefore$ **The correct choice is (c).**




**What if ...** the light source is kept fixed while rotating mirror (2) by an angle of 5° such that the angle between the two mirrors increases, **what happens to** the value of angle $\grave{\phi}_2$?

## Test yourself

**1** ✱ The opposite figure shows three mirrors A , B and C. If a light ray falls on mirror A as shown in the figure, **trace** the path of the ray till it gets reflected from mirror C.



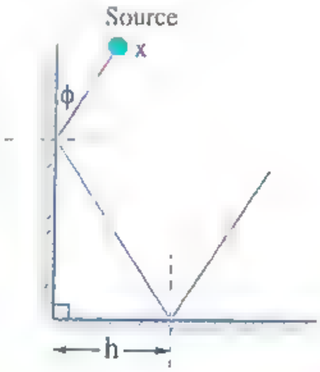
## Choose the correct answer.

(1) In the opposite figure, a laser ray is incident on mirror (1) to get reflected from it and fall on mirror (2). Using the shown angles, after the ray gets reflected on mirror (2), it passes through point .......... .


(a) A (b) B

(c) C (d) D

(2) In the opposite figure, when moving light source x to increase angle ϕ, the distance h which is shown in the figure .......... .




(a) will increase

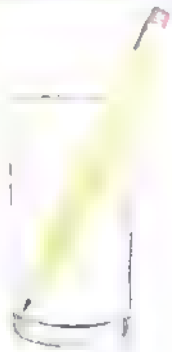
(b) will decrease

(c) may increase or decrease

(d) won't change

## Third Light refraction

- If you put a pen in a glass of water and looked at it from the side, you will see the pen as if it has been broken and this happens due to **the refraction of light**.

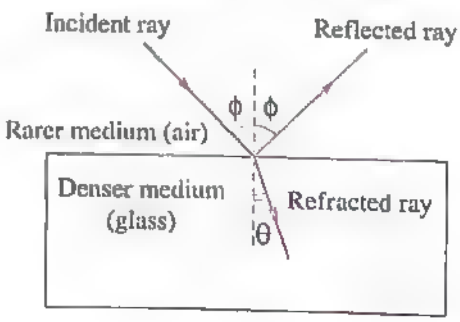


### Occurrence:

When a beam of a parallel light rays falls on the interface (boundary surface) between two transparent media of different optical densities;

1. Part of the light gets reflected in the first medium.
2. Part of light passes to the second medium deviated from its direction and this phenomenon is known as **light refraction**.
3. Very small part of light gets absorbed in the second medium.

**Optical density of a medium:**
The ability of the medium to bend light rays when they enter into it.



➲ **From the previous, we can define light refraction and the angle of refraction as follows:**

**Light refraction**

It is a phenomenon that changes light's direction when it travels slanted through the interface between two transparent media of different optical densities.

**The angle of refraction (θ)**

It is the angle between the refracted light ray and the normal line on the interface between the two media at the point of incidence.

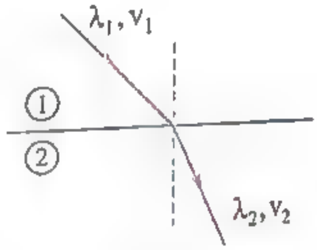
⊙ **Why it happens?**

- The refraction of light occurs due to the different speeds of light in the two media as a result of the different optical densities of the two media.

⊙ **Light refraction obeys two laws, which are:**

**First law**

The ratio between the sine of the angle of incidence ($\sin\phi$) in the first medium to the sine of the angle of refraction ($\sin\theta$) in the second medium equals the ratio of the speed of light ($v_1$) in the first medium to the speed of light ($v_2$) in the second medium which is a constant ratio for those two media and it is called relative refractive index from the first medium to the second medium (${}_1n_2$).




$${}_1n_2 = \frac{\sin\phi}{\sin\theta} = \frac{v_1}{v_2} = \frac{\lambda_1}{\lambda_2}$$

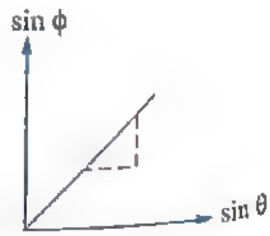
**Second law**

The incident light ray, the refracted light ray and the normal line at the point of incidence all lie in the same plane which is perpendicular to the interface between the two media.

**From the first law**

It is obvious that $\sin\phi \propto \sin\theta$

So, when plotting the relation between $\sin\phi$ and $\sin\theta$, we get a straight line as in the opposite graph whose slope represents the relative refractive index between the two media.




$$\text{Slope} = \frac{\Delta \sin\phi}{\Delta \sin\theta} = {}_1n_2$$

➲ **From the previous, we can deduce that when a light ray falls on the interface between two transparent media such that it travels from:**

medium

denser medium

medium

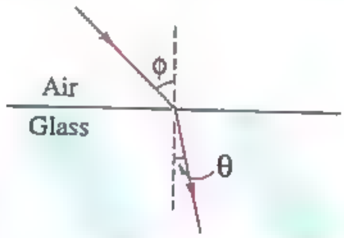
**Such as**

From air to glass

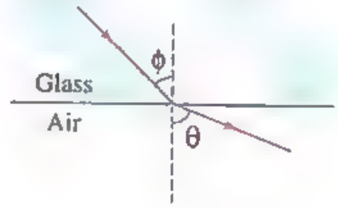
From glass to air

**So, the light ray is refracted (bent)**

toward the normal on the interface ($\phi > \theta$)

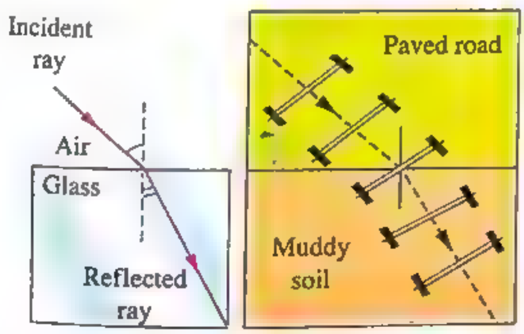



away from the normal on the interface ($\phi < \theta$)

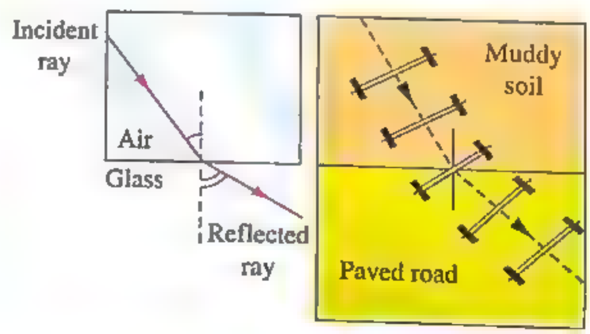



**This can be resembled by**

a cart moving on a paved road when one of its wheels enters a muddy soil, the soil slows down this wheel, while the other wheel keeps moving on the paved road faster than the first one, therefore the path of motion gets bent.




a cart moving on a muddy soil when one of its wheels enters a paved road, so it moves faster, while the other wheel keeps moving in the muddy soil slower than the first one, therefore the path of motion gets bent.



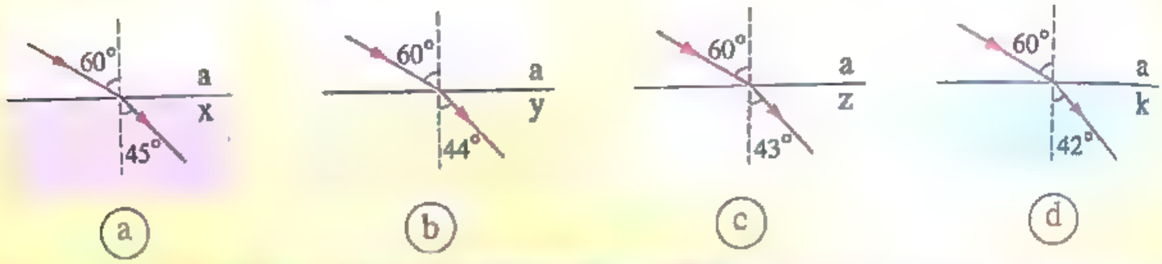

## The factors affecting the relative refractive index between two media:

1. The types of the two media (their optical densities).
2. The wavelength of the incident light ray.

## 2 Test yourself

**✱ Choose the correct answer:**

The four following figures represent four rays of a light that has a wavelength (λ) travelling from medium A to other four different media x, y , z and k each one at a time. In which of these media (x, y, z or k) the light ray will have the longest wavelength?




### The absolute refractive index of a medium

⊙ If a light ray passes from space or air into another transparent medium (given that the speed of light in air is nearly equal to its speed in space):


The absolute refractive index of the medium (n) "Constant value for the medium"

- = The ratio of the speed of light in space or air (c) to its speed in the medium (v) — $n = \frac{c}{v}$
- = The ratio of the wavelength of light in air ($\lambda_{air}$) to its wavelength in the medium ($\lambda_{medium}$) — $n = \frac{\lambda_{air}}{\lambda_{medium}}$
- = The ratio of the sine of the angle of incidence in the space or the air (sin ϕ) to the sine of the angle of refraction in the medium (sin θ) — $n = \frac{\sin\phi}{\sin\theta}$

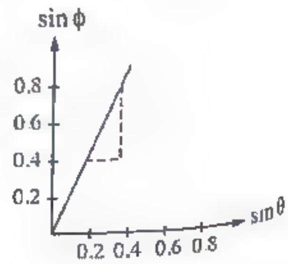
**➲ From the previous, we can deduce that:**

⊙ The absolute refractive index of any medium is always greater than one because the speed of light in space or air is a universal constant that equals to $3 \times 10^8$ m/s and it is greater than its speed in any other medium.

⊙ The refractive index has no measuring units because it is a ratio between two similar physical quantities.

⊙ The speed of light in a medium is inversely proportional to the absolute refractive index of this medium ($v \propto \frac{1}{n}$).

⊙ When plotting the relation between (sin ϕ) for a light ray in air and (sin θ) in any other medium, we get a straight line as in the opposite graph whose slope is always greater than one and represents the absolute refractive index (n) for this medium.




$$\text{Slope} = \frac{\Delta \sin\phi}{\Delta \sin\theta} = n$$

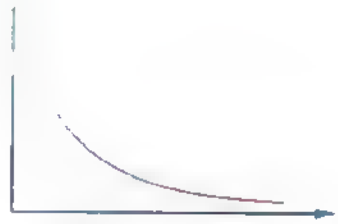
## The factors affecting [illegible]

**1. The type of medium material:**

As the optical density of the medium increases its refractive index increases.

**2. The wavelength of the incident light ray:**

The refractive index of a medium decreases as the wavelength of the incident light increases and the opposite graph represents the relation between the absolute refractive index (n) of one type of glass and the wavelength (λ) of the light passing through it.




## Deducing the relation between the relative refractive index for two media and their absolute refractive indices:

$$\because n = \frac{c}{v} \quad , \quad v = \frac{c}{n} \qquad \therefore \frac{v_1}{v_2} = \frac{n_2}{n_1}$$

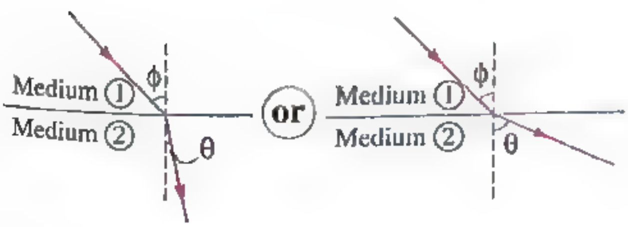
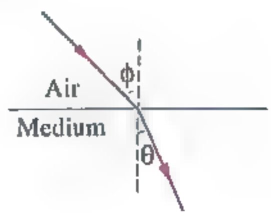
$$\because {}_1n_2 = \frac{v_1}{v_2} \qquad \therefore {}_1n_2 = \frac{n_2}{n_1}$$

*i.e.*

| | | | | |
|---|---|---|---|---|
| The relative refractive index from the first medium to the second medium | ${}_1n_2$ | = | The absolute refractive index of the second medium ÷ that of the first medium | $\frac{n_2}{n_1}$ |

And, accordingly the relative refractive index from the second medium to the first medium can be obtained from the relation: $\left( {}_2n_1 = \frac{n_1}{n_2} = \frac{1}{{}_1n_2} \right)$

➲ **From the previous, we can compare between the relative refractive index between two media and the absolute refractive index of a medium as follows:**

| **Relative refractive index between two media** | **Absolute refractive index of a medium** |
|---|---|
| **Illustrative diagram** | |
|   |   |

### Concept

| | |
|---|---|
| The ratio of the sine of the angle of incidence in the first medium to the sine of the angle of refraction in the second medium.<br>or<br>The ratio of the speed of light in the first medium to the speed of light in the second medium. | The ratio of the sine of the angle of incidence in space or air to the [illegible] angle of refraction in the medium.<br>or<br>The ratio of the speed of light in space or air to the speed of light in the medium. |

### Mathematical relation

| | |
|---|---|
| $_1n_2 = \frac{\sin\phi}{\sin\theta} = \frac{v_1}{v_2} = \frac{\lambda_1}{\lambda_2}$ | $n = \frac{\sin\phi}{\sin\theta} = \frac{c}{v} = \frac{\lambda_{air}}{\lambda_{medium}}$ |

### Magnitude

| | |
|---|---|
| Might be less or greater than one | Always greater than one |

### The factors on which it depends

| | |
|---|---|
| • The wavelength of the incident light.<br>• The types of the two media. | • The wavelength of the incident light.<br>• The type of medium. |

### Measuring unit

None of them has a measuring unit since each of them is a ratio between two similar physical quantities

## Snell's law

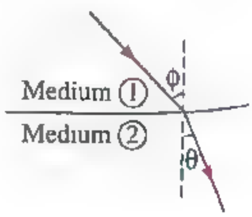
⊙ From the first law of refraction:

$$\because \; _1n_2 = \frac{\sin\phi}{\sin\theta}$$

$$, \because \; _1n_2 = \frac{n_2}{n_1}$$

$$\therefore \frac{\sin\phi}{\sin\theta} = \frac{n_2}{n_1}$$

$$\boxed{\underbrace{n_1}_{\text{First medium}} \sin\phi = \underbrace{n_2}_{\text{Second medium}} \sin\theta}$$



# Notes :

(1) **The light ray that falls perpendicularly on the boundary between two transparent media, doesn't suffer any refraction !** when the light ray falls normally on ①
the boundary surface between the two media ($\phi = 0°$) ②
according to Snell's law ($n_1 \sin \phi = n_2 \sin \theta$), then ($n_2 \sin \theta = 0$) and the angle of refraction ($\theta = 0°$),

## Note that:

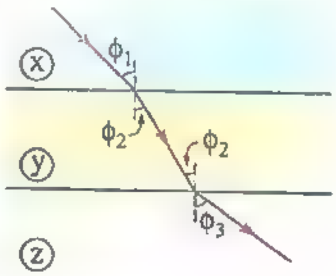
$\lambda_1 \neq \lambda_2$ | $v_1 \neq v_2$ | $\upsilon_1 = \upsilon_2$ | $\theta = 0$ | $\phi = 0$

(2) The relative refractive index from the first medium to the second medium ($_1n_2$) can be calculated as follows:

**By knowing**

| The relative refractive index | The absolute refractive indices | The angles | The wavelengths | The speeds |
|---|---|---|---|---|
| $_1n_2 = \frac{1}{_2n_1}$ | $_1n_2 = \frac{n_2}{n_1}$ | $_1n_2 = \frac{\sin \phi}{\sin \theta}$ | $_1n_2 = \frac{\lambda_1}{\lambda_2}$ | $_1n_2 = \frac{v_1}{v_2}$ |

(3) When the light ray passes successively through three media x, y and z of refractive indices $n_x$, $n_y$ and $n_z$ respectively, the angle $\phi_3$;




- depends on $n_x$, $n_z$ and $\phi_1$
- doesn't depend on $n_y$,

**Since:**

$\because n_x \sin \phi_1 = n_y \sin \phi_2$ ①

$\because n_y \sin \phi_2 = n_z \sin \phi_3$ ②

From equations ① and ②:

$\therefore n_x \sin \phi_1 = n_z \sin \phi_3$

$\therefore \sin \phi_3 = \frac{n_x}{n_z} \sin \phi_1$

This also holds true for more than three media when a light ray passes successively through them.

(4) When a light ray travels from medium (1) to medium (2)

$$n_1 \sin\phi = n_2 \sin\theta \quad , \quad \sin\theta = \frac{n_1}{n_2} \sin\phi$$

**And if**

$n_1 > n_2$ | $n_1 < n_2$

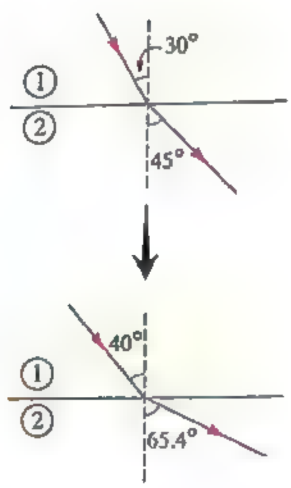
**Then**

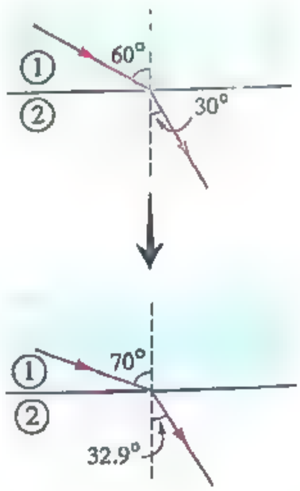
$\phi < \theta$ | $\phi > \theta$

**So, when increasing the angles of incidence ($\phi$) with a given value, the angles of refraction ($\theta$) increase with**

| **A greater value** | **A lower value** |
|---|---|
| Where: $\frac{n_1}{n_2} > 1$ | Where: $\frac{n_1}{n_2} < 1$ |

**Example**




## Example 1

*If the absolute refractive index of water is $\frac{4}{3}$ and the absolute refractive index of glass is $\frac{3}{2}$, calculate:*

*(a)* The relative refractive index from water to glass.

*(b)* The relative refractive index from glass to water.

## Solution

$n_w = \frac{4}{3}$ , $n_g$ [illegible]

(a) ${}_w n_g$ [illegible]

(b) ${}_g n_w = \frac{n_w}{n_g} = \frac{\frac{4}{3}}{\frac{3}{2}} = \frac{8}{9} =$ [illegible]

### Another Solution:

$${}_g n_w = \frac{1}{{}_w n_g} = \frac{1}{\frac{9}{8}} = \frac{8}{9} = 0.889$$

**What if** you are asked to calculate the ratio between the speed of light in water to its speed in glass, **what** will be your answer?

## Example 2

*A light ray of wavelength 589 nm is incident in air on the surface of a glass plate of refractive index 1.52 at an angle of incidence 30°, calculate:*

*(a)* The angle of refraction of the ray.

*(b)* The speed of light inside the glass.

*(c)* The wavelength of light inside the glass.

*(The speed of light in air = $3 \times 10^8$ m/s)*

## Solution

| | | | | | | |
|---|---|---|---|---|---|---|
| $\lambda_a = 589$ nm | $n = 1.52$ | $\phi = 30°$ | $c = 3 \times 10^8$ m/s | $\theta = ?$ | $v = ?$ | $\lambda_g = ?$ |

(a) $n = \frac{\sin \phi}{\sin \theta}$

$$\sin \theta = \frac{\sin \phi}{n} = \frac{\sin 30}{1.52} \quad , \quad \therefore \theta = 19.2°$$

(b) $n = \frac{c}{v}$

$$v = \frac{c}{n} = \frac{3 \times 10^8}{1.52} = 1.97 \times 10^8 \text{ m/s}$$

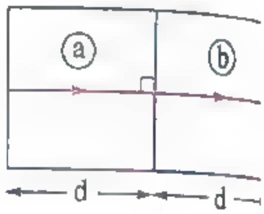
(c) $\because v_a = v_g$ $\therefore \frac{c}{\lambda_a} = \frac{v}{\lambda_g}$ $\therefore n = \frac{\lambda_a}{\lambda_g}$

$$\lambda_g = \frac{\lambda_a}{n} = \frac{589}{1.52} = 387.5 \text{ nm}$$

**What if** the angle of incidence of the light ray on the surface of glass is changed, **which** of the previously calculated values in (a), (b) or (c) will change?

## Example 3

*The opposite figure shows a light ray falling perpendicular on the interface from medium ⓐ to another medium ⓑ, if the number of light waves in medium ⓐ equals $10^5$ waves and the number of light waves in medium ⓑ equals $1.5 \times 10^5$ waves, find the relative refractive index ${}_a n_b$.*




### Solution

$N_a = 10^5$ $N_b = 1.5 \times 10^5$ ${}_a n_b = ?$

$$\lambda = \frac{x}{N}$$

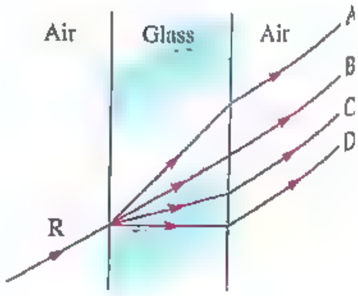
$$\lambda_a = \frac{d}{10^5} \quad , \quad \lambda_b = \frac{d}{1.5 \times 10^5}$$

$${}_a n_b = \frac{v_a}{v_b} = \frac{\lambda_a}{\lambda_b} = \frac{d \times 1.5 \times 10^5}{10^5 \times d} = 1.5$$

**What if** you are asked to determine the medium (ⓐ or ⓑ) in which the frequency of light is higher, **what** will be your answer?

## Example 4

*The opposite figure represents a light ray (R) passing from air through a glass sheet then into air again, so correct path in which the ray moves is path ………… .*




ⓐ A ⓑ B

ⓒ C ⓓ D

## Solution

$\because n_{glass} > n_{air}$

$\because n_{glass} = \dfrac{\sin \phi_{air}}{\sin \theta_{glass}}$

$\therefore \phi_{air} > \theta_{glass}$

**Clue**

*To determine the correct path of the light ray, the normal lines to the boundary surfaces must be drawn at each point of incidence for determining either if the ray passes in a straight line, bends towards the normal or away from it*

*i.e.*, the lig

in glass.

$\therefore$ At the boundary surface between air and glass, the light ray refracts towards the normal and at the boundary surface between glass and air, the light ray refracts away from the normal.

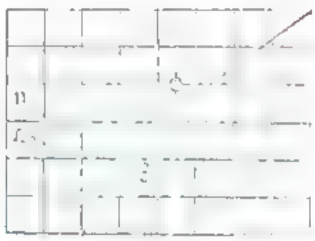
$\therefore$ **The correct path for the light ray is C.**

$\therefore$ **The correct choice is ⓒ.**

**What if** you assumed that the sheet is made of diamond, bearing in mind that the refractive index of diamond is greater than the refractive index of glass, **will** the angle at which the light ray emerges into air change?

## Example 5

*The opposite figure represents with a definite drawing scale a red light ray while passing between two media, so the relative refractive index between those two media ($_1n_2$) equals ........*

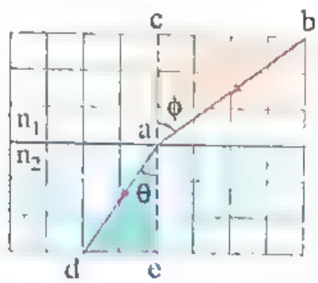


ⓐ 1.44 ⓑ 1.18

ⓒ 1.13 ⓓ 0.88

## Solution

The angle of incidence and the angle of refraction can be determined from the dimensions shown in the figure:




$\because \tan \alpha = \dfrac{\text{Opposite}}{\text{Adjacent}}$

$\therefore \tan \phi = \dfrac{4}{3}$ $\therefore \phi = 53.13°$

$\therefore \tan \theta = \dfrac{2}{3}$ $\therefore \theta = 33.69°$

$_1n_2 = \dfrac{\sin \phi}{\sin \theta} = \dfrac{\sin 53.13}{\sin 33.69}$

$= \mathbf{1.44}$

## Another Solution:

- In triangle abc :

$$ab = \sqrt{(ac)^2 + (bc)^2}$$

$$= \sqrt{(3)^2 + (4)^2} = 5 \text{ units}$$

$$\sin\phi = \frac{\text{Opposite}}{\text{Hypotenuse}} = \frac{bc}{ab} = \frac{4}{5}$$

- In triangle ade :

$$ad = \sqrt{(ae)^2 + (de)^2}$$

$$= \sqrt{(3)^2 + (2)^2} = \sqrt{13} \text{ units}$$

$$\sin\theta = \frac{de}{ad} = \frac{2}{\sqrt{13}}$$

$$_1n_2 = \frac{\sin\phi}{\sin\theta} = \frac{\frac{4}{5}}{\frac{2}{\sqrt{13}}} = 1.44$$

∴ **The correct choice is ⓐ.**

**What if** a blue light ray falls instead of the red light ray, **will** the value of the relative refractive index between the same two media ($_1n_2$) change?

## 3 Test yourself

Answer

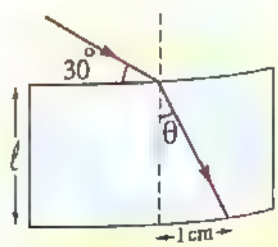
**1** ✱ A light ray falls on the surface of a glass of refractive index 1.5 at an angle of incidence 60°, if a small part of the light gets reflected and another part gets refracted, **calculate** the angle between the reflected and the refracted light rays.

..................................................................................................................

..................................................................................................................

..................................................................................................................

**2** ✱ The opposite figure shows a light ray falling on a glass slab of thickness $\ell$, if the refractive index of the slab is $\sqrt{3}$, **calculate** its thickness $\ell$.




..................................................................................................................

..................................................................................................................

..................................................................................................................

## 3 Choose the correct answer:

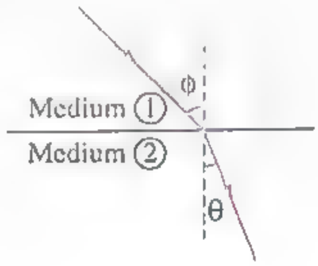
(1) The opposite figure shows a light ray falling on a glass cuboid to get refracted inside it, hence the speed of light ray in glass is approximately equal to

(Giv[illegible] $\times 10^8$ m/s)

ⓐ $1.8 \times 10^8$ m/s

ⓒ $2.3 \times 10^8$ m/s  ⓓ $2.5 \times 10^8$ m/s

(2) In the opposite figure, a light ray travels from medium ① to medium ②. If the angle $\phi$ has increased by a value of 5°, angle $\theta$ ..... ........ .



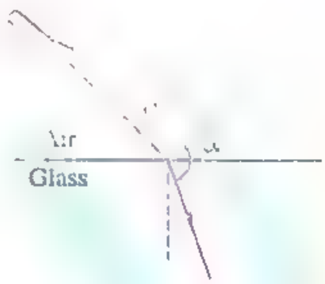

ⓐ increases by a value of 5°

ⓑ increases by a value greater than 5°

ⓒ increases by a value smaller than 5°

ⓓ doesn't change

(3) In the opposite figure, a light ray passes from air into a glass cuboid. If the angle of incidence of the ray ($\phi$) gets increased, the angle $\alpha$ between the reflected and the refracted light rays .............. .




ⓐ will increase

ⓑ will decrease

ⓒ may increase or decrease

ⓓ won't change

Chapter 2

Questions on Lesson One

# Properti[illegible] of Light

## (Propagation, R[illegible]ction an[illegible] [illegible]action)

To watch videos how to solve ques[illegible] use the App

The questions signed by ✱ are answered in detail. Understand[illegible] O[illegible] Higher Order Thinking Skills

Interactive [illegible]

## First Multiple choice questions

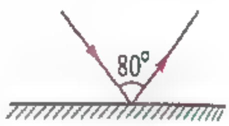
### Light reflection

| Spectrum | Wavelength |
|---|---|
| Visible light | M |
| Gamma rays | Y |
| X-rays | Z |

1. If the opposite table shows some selected wavelengths from the electromagnetic spectrum in air, so .............

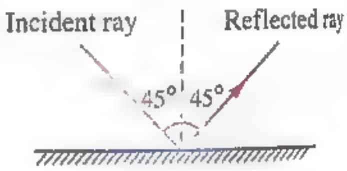
   (a) $M < Z < Y$ (b) $Y < Z < M$
   (c) $Y < Z = M$ (d) $Y = Z > M$

2. The opposite figure shows a light ray falling on the surface of a plane mirror and bouncing back, hence the angle of reflection of the ray from the surface of the mirror equals .............



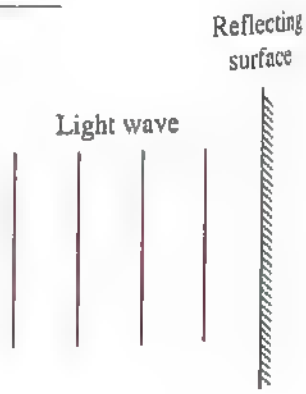

   (a) 40° (b) 50° (c) 80° (d) 100°

3. In the opposite figure, a light ray is incident with a speed v on the surface of a mirror and gets reflected from it, so the speed of the ray after its reflection becomes .............




   (a) $\frac{1}{\sqrt{2}}$ v (b) v
   (c) $\sqrt{2}$ v (d) 2 v

4. The opposite figure shows a light wave being incident on a reflecting surface, what will be the value of the angle of reflection for this wave after striking the reflecting surface?

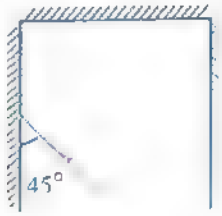


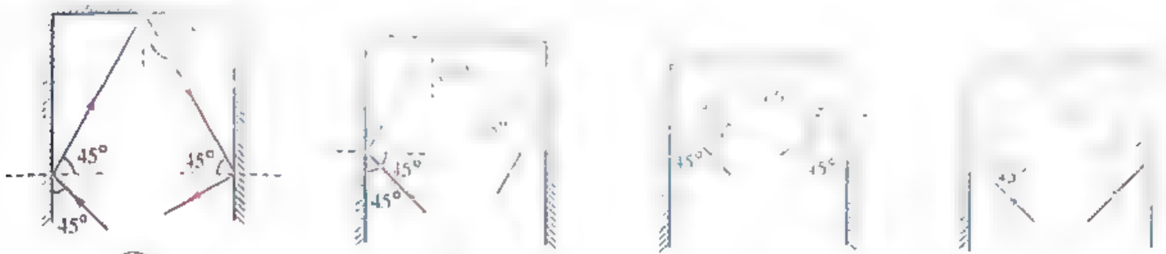

   (a) 0° (b) 45°
   (c) 90° (d) 180°

5. ✱ If a light ray is incident perpendicular to a plane mirror, the angle of deviation of the ray from its path equals .............

   (a) 0° (b) 90° (c) 180° (d) 360°

**6** The opposite figure represents three plane mirrors forming three sides of a square. Which of the following choices shows the path of the incident light ray as it gets reflected by the three mirrors?




ⓐ ⓑ ⓒ ⓓ

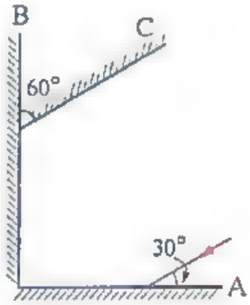
**7** ✻ In the opposite figure, which of the following statements is correct?

ⓐ The ray is reflected from mirror C at an angle of 30°

ⓑ The ray is reflected from mirror C at an angle of 45°

ⓒ The ray is reflected from mirror C at an angle of 60°

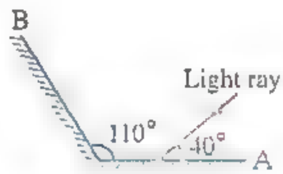
ⓓ The ray is reflected parallel to mirror C.




**8** ✻ In the opposite figure, the angle of reflection of the light ray from mirror B equals ..............

ⓐ 20° ⓑ 40°

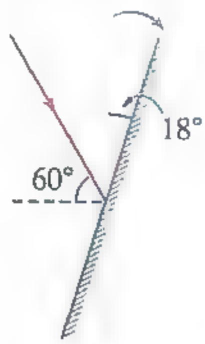
ⓒ 60° ⓓ 70°




**9** ✻ A light ray is incident on a plane mirror with an angle of 60°. If the mirror is rotated by an angle of 18° in the clockwise direction while keeping the incident ray in the same direction as in the figure, then the angle of reflection becomes ..............

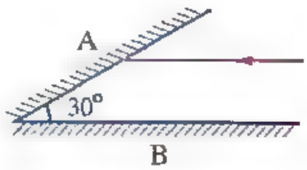
ⓐ 18° ⓑ 42°

ⓒ 48° ⓓ 78°




**10** ✻ If a light ray is incident on mirror A while being parallel to mirror B as shown in the opposite figure:

(i) The light ray gets reflected from mirror A and falls on mirror B by an angle of incidence that equals ..........



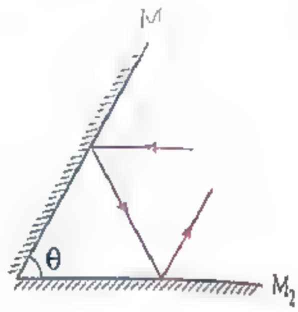

ⓐ 90° ⓑ 60° ⓒ 30° ⓓ 0°

(ii) The reflected light ray from mirror B falls again on mirror A with an angle of incidence that equals ............ .

ⓐ 90° ⓑ 45° ⓒ 30°

---

11 ✻ In the opposite figure, a light ray is incident on mirror $M_1$ parallel to mirror $M_2$, hence the ray gets reflected from mirror $M_1$ to fall on mirror $M_2$ and get reflected from it parallel to mirror $M_1$, so angle θ equals ............

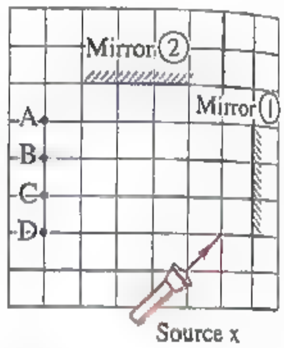



ⓐ 30° ⓑ 45°

ⓒ 60° ⓓ 90°

---

12 ✻ The opposite figure shows with a definite drawing scale the incidence of a laser ray from source x on mirror ①, hence after the ray gets reflected from mirror ②, it passes through point ............ .

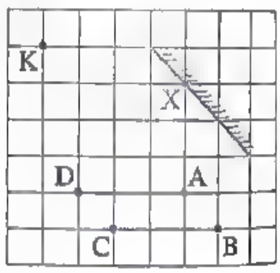



ⓐ A ⓑ B

ⓒ C ⓓ D

---

13 ✻ The opposite figure shows with a definite drawing scale the positions of four light sources (A, B, C and D) in front of a plane mirror, so the light ray that is reflected on the mirror at point X and passes through point K is coming from ............ .

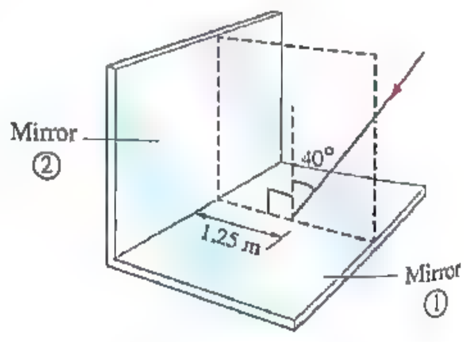



ⓐ source A ⓑ source B

ⓒ source C ⓓ source D

---

14 ✻ The opposite figure represents two perpendicular plane mirrors ①, ②. A light ray is incident on mirror ① at an angle of 40°, so:




(i) The angle of reflection of the ray from mirror ② equals ............ .

ⓐ 40° ⓑ 50°

ⓒ 60° ⓓ 90°

(ii) The distance covered by the reflected ray from the position of its reflection from mirror ① till striking mirror ② equals ............ .

ⓐ 0.8 m ⓑ 0.98 m ⓒ 1.94 m ⓓ 2.5 m

## Light refraction

15. When a light ray is incident from air with an acute angle on a glass surface, its direction gets change due to the change of ............ between the two media.

(a) the amplitude of light wave (b) the color of light

(c) the frequency of light (d) the [illegible]

16. When a lig[illegible] medium with an [illegible] not change?

(a) The wave speed (b) The wavelength

(c) The direction of propagation (d) The wave amplitude (intensity)

17. When a light ray falls on the interface between two media at an angle of incidence $\phi$ and gets refracted at an angle of refraction $\theta$, the ratio $\frac{\sin \phi}{\sin \theta}$ is ........ ...

(a) constant for the two media (b) variable according to the value of $\phi$

(c) constant and always greater than one (d) constant and always less than one

18. The opposite figure shows a light ray that is incident on a glass slab, so the two numbers denoting each of the angle of incidence and the angle of refraction are ............ .

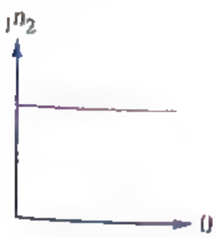

| | The angle of incidence | The angle of refraction |
|---|---|---|
| (a) | angle 1 | angle 3 |
| (b) | angle 1 | angle 4 |
| (c) | angle 2 | angle 3 |
| (d) | angle 2 | angle 4 |

19. When the angle of incidence on the boundary surface between two media gets doubled, the relative refractive index between them ..............

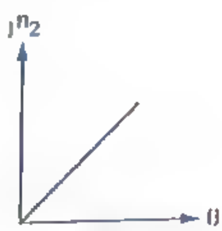
(a) decreases to its half (b) gets doubled

(c) remains constant (d) gets tripled

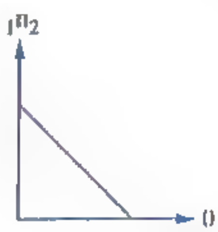
20. Which of the following graphs represents the relation between the relative refractive index between two media and the angle of refraction in one of them?



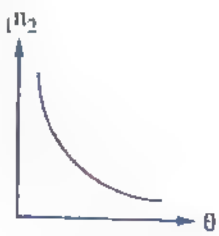

(a)




(b)

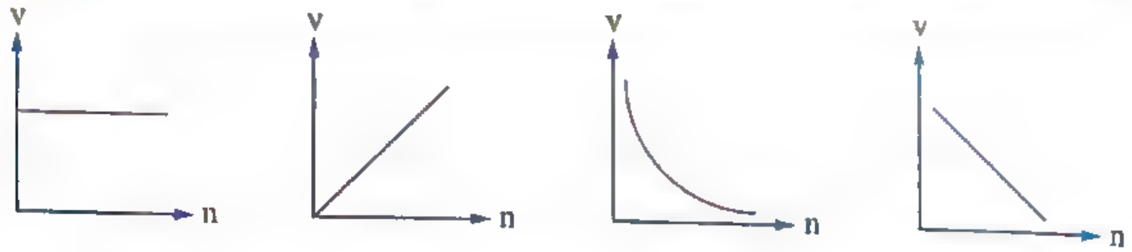



(c)




(d)

**21** Which of the following graphs represents the variation of the speed of light (v) through different materials versus the absolute refractive index (n) for each of these materials?

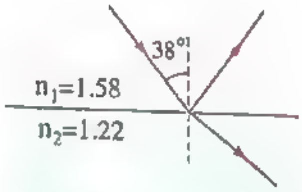



ⓐ ⓑ ⓒ ⓓ

**22** When a light ray is incident from air on water surface at an angle of incidence 60°, the angle of refraction will be ..........

ⓐ greater than 60° ⓑ less than 60° ⓒ equal to 60° ⓓ equal to 0°

**23** ✻ From the opposite figure, the values of the angle of reflection and the angle of refraction are ............ , .............




| | The angle of reflection | The angle of refraction |
|---|---|---|
| ⓐ | 38° | 68.38° |
| ⓑ | 52.88° | 38° |
| ⓒ | 28.38° | 38° |
| ⓓ | 38° | 52.88° |

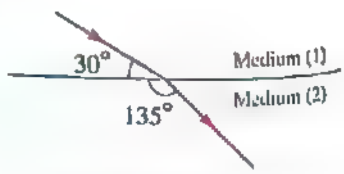
**24** If a light ray is incident on a surface of a cuboid that has an absolute refractive index of $\sqrt{3}$ at an angle of incidence 60°, the angle of refraction of the light ray equals ............ .

ⓐ 30° ⓑ 45° ⓒ 60° ⓓ 90°

**25** A light ray is incident on the boundary surface between two media. If the angle of incidence is 60° in medium (1) and the angle of refraction is 30° in medium (2), the relative refractive index from medium (1) to medium (2) equals ..........

ⓐ 2 ⓑ $\sqrt{3}$ ⓒ $\sqrt{2}$ ⓓ $\frac{1}{2}$

**26** The opposite figure shows a light ray falling from medium (1) on the boundary surface with medium (2), so the relative refractive index from medium (1) to medium (2) equals ............ .




ⓐ 1.52 ⓑ 1.48
ⓒ 1.34 ⓓ 1.22

27 ✱ A light ray is incident from air on the surface of a glass slab at an angle of 52°. If the ray is deviated by an angle of 19°, the refractive index of glass is ............ .

ⓐ 0.83 ⓑ 1.33 ⓒ 1.45 ⓓ 1.65

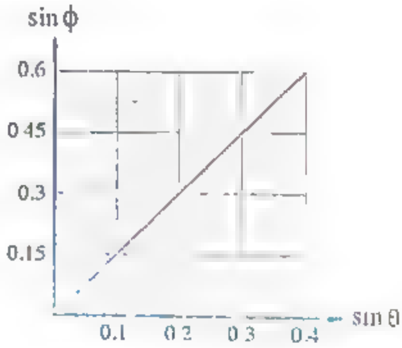
28 If the absolute refractive index of gasoline $n_1 = 1.5$ and the absolute refractive index of flint glass $n_2 = 1.65$, so the relative refractive index from gasoline to flint glass ($_1n_2$) equals ............ .

ⓐ 0.91 ⓑ 1.1 ⓒ 1.25 ⓓ 1.5

29 ✱ A light ray is incident from air inclined to a glass surface at an angle of 50° with the surface. If the speed of light in air is $3 \times 10^8$ m/s and in glass is $1.92 \times 10^8$ m/s, then the angle of refraction of the light ray in the glass equals ............ .

ⓐ 24.29° ⓑ 29.34° ⓒ 40° ⓓ 50°

30 ✱ The opposite graph represents the relation between the sine of the angle of incidence in a transparent medium (1) and the sine of the angle of refraction in another medium (2) when a light ray travels between them. If the speed of light in medium (1) is $2 \times 10^8$ m/s, then:




(i) The relative refractive index from medium (1) to medium (2) equals ............ .

ⓐ 1.5 ⓑ 0.75 ⓒ 1.93 ⓓ 2

(ii) The speed of light in medium (2) equals ............ .

ⓐ $2.33 \times 10^8$ m/s ⓑ $2 \times 10^8$ m/s ⓒ $1.5 \times 10^8$ m/s ⓓ $1.33 \times 10^8$ m/s

31 When a ray of light that has wavelength $\lambda$ and frequency $\upsilon$ moves from air into another transparent medium of refractive index n, the frequency and the wavelength of that light in the transparent medium will be ............ .

| | The frequency of the light in the medium | The wavelength of the light in the medium |
|---|---|---|
| ⓐ | $\upsilon$ | $\lambda$ |
| ⓑ | $\upsilon$ | $\frac{\lambda}{n}$ |
| ⓒ | $\frac{\upsilon}{n}$ | $\lambda n$ |
| ⓓ | $\upsilon n$ | $\lambda$ |

32 A red light ray is incident from air on the surface of glass. If the wavelength of red light in air is 7000 Å and the refractive index of glass is 1.5, the wavelength of red light in glass is ............ .

ⓐ 10500 Å ⓑ 8564 Å ⓒ 5543 Å ⓓ 4667 Å

33 ✱ A ray of light whose wavelength is 700 nm in air and 526 nm in water travels in water with a speed of ............ . (Take: $c = 3 \times 10^8$ m/s)

ⓐ $2.25 \times 10^8$ m/s ⓑ $2 \times 10^8$ m/s ⓒ $1.89 \times 10^8$ m/s ⓓ $1.76 \times 10^8$ m/s

34 If the ratio between the absolute refractive index of the first medium and the absolute refractive index of the second medium is $\frac{2}{1}$, the ratio between the speed of light in the first medium and the speed of light in the second medium is ............ .

ⓐ $\frac{2}{1}$ ⓑ $\frac{1}{2}$ ⓒ $\frac{4}{1}$ ⓓ $\frac{1}{4}$

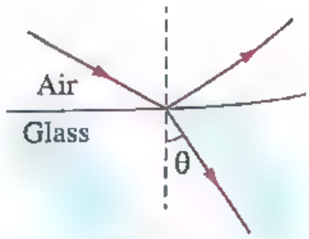
35 When a light ray is incident at an acute angle from a medium of refractive index 1.2 onto the surface of another medium of refractive index 1.5, then ............ .

| | The speed of light | The ray gets refracted |
|---|---|---|
| ⓐ | increases | toward the normal line |
| ⓑ | decreases | toward the normal line |
| ⓒ | decreases | away from the normal line |
| ⓓ | increases | away from the normal line |

36 A light ray is incident from air onto the surface of a transparent material at an angle of 45°, so the angle of refraction inside the material may equal ............ .

ⓐ 37° ⓑ 90° ⓒ 60° ⓓ 75°

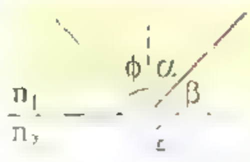
37 In the opposite figure, a light ray is incident on a glass slab of refractive index 1.5, the reflected and the refracted rays are perpendicular to each other, so the angle of refraction (θ) equals ............ .




ⓐ 42.14° ⓑ 37.25°

ⓒ 33.69° ⓓ 27.64°

**38** In the opposite figure, when increasing the angle of incidence ($\phi$) for the light ray, the angle that decreases is ...

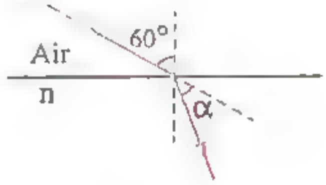



ⓐ angle $\alpha$ ⓑ angle $\beta$

ⓒ angle $\theta$ ⓓ all of them

---

**39** In the opposite figure, which of the following values of refractive index (n) makes angle $\alpha$ have the greatest value?

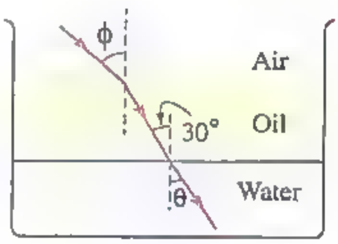



ⓐ 1.2 ⓑ 1.3

ⓒ 1.4 ⓓ 1.5

---

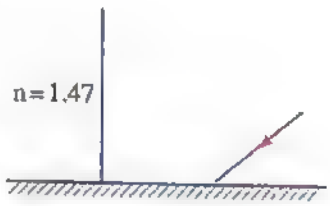
**40** ✻ The opposite figure shows a light ray travelling from air into oil then into water. If the absolute refractive index of oil is 1.48 and of water is 1.33, then the angles $\phi$ , $\theta$ are ............ , ............ .




| | $\phi$ | $\theta$ |
|---|---|---|
| ⓐ | 41.6° | 33.81° |
| ⓑ | 41.6° | 41.6° |
| ⓒ | 47.73° | 33.81° |
| ⓓ | 47.73° | 41.6° |

---

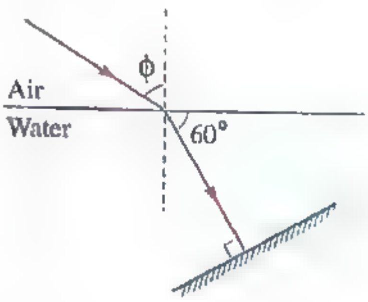
**41** The opposite figure shows a glass plate which is put perpendicular to the surface of a horizontal plane mirror. If a light ray falls at an angle of incidence 50° on the surface of the mirror, its angle of refraction in the glass plate will be ............ .




ⓐ 51.6° ⓑ 47.2° ⓒ 35.8° ⓓ 25.9°

---

**42** ✻ In the opposite figure, a light ray passes from air into water, then gets reflected by a plane mirror under the surface of water, hence: (Take: $n_{water} = 1.33$)




**(i)** The angle of incidence ($\phi$) equals ............ .

ⓐ 22.41° ⓑ 30.58°

ⓒ 41.68° ⓓ 60.12°

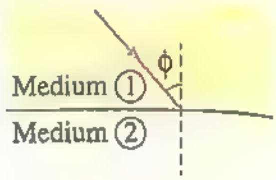
**(ii)** The angle of refraction when the ray emerges from water equals ............ .

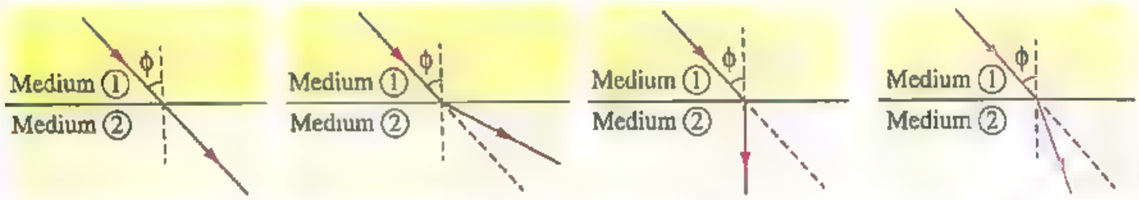
ⓐ 60° ⓑ 41.68° ⓒ 30.58° ⓓ 22.41°

43 ✻ A light ray is incident from air on one of the sides of a glass cuboid and came out from the opposite side to air with an angle of refraction 50°. If the refractive index of glass is 1.53, so ............ , ............ .

| | The angle of incidence in air | The angle of [illegible] cuboid |
|---|---|---|
| ⓐ | 40° | 30° |
| ⓑ | 40° | 45° |
| ⓒ | 50° | 30° |
| ⓓ | 50° | 45° |

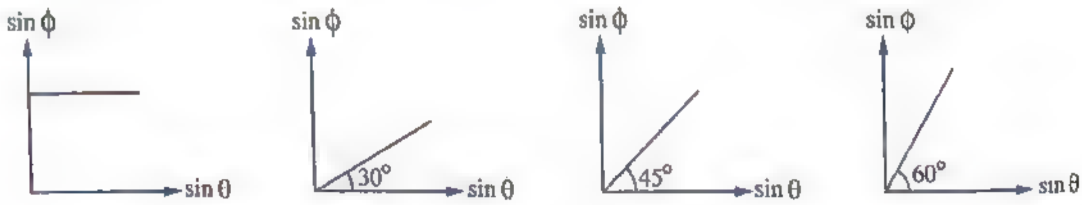
44 In the opposite figure, a light ray is incident with an angle $\phi$ on the boundary surface between two media ①, ②, hence if the ratio between the wavelengths of the incident light in the two media is $\frac{\lambda_1}{\lambda_2} = \frac{3}{2}$, the figure that represents the correct path of the ray is ............ .



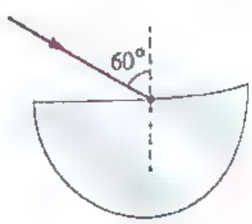

ⓐ ⓑ ⓒ ⓓ

45 If a light ray travelled from a medium of refractive index $n_1$ to another medium of refractive index $n_2$ where $n_2 > n_1$, the proper graph of $\sin \phi$ versus $\sin \theta$, when they are drawn with the same scale, will be ............ .



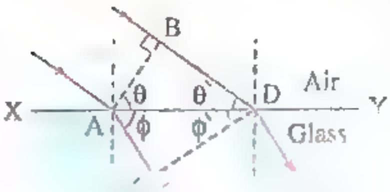

ⓐ ⓑ ⓒ ⓓ

46 In the opposite figure, a light ray is incident in air on the surface at the center of a glass semi sphere, so if the refractive index of glass is 1.5, the angle of emergence of the light ray from the glass equals ............ .




ⓐ 0° ⓑ 30°
ⓒ 45° ⓓ 60°

47 ✻ In the opposite figure, a wave of light passes from air into glass through the boundary surface XY, so AB represents the incident wavefront and CD represents the refracted wavefront, hence the refractive index of glass equals ..........




ⓐ $\frac{\sin\theta}{\sin\grave{\theta}}$ ⓑ $\frac{\sin\phi}{\sin\theta}$ ⓒ $\frac{\sin\grave{\theta}}{\sin\grave{\phi}}$ ⓓ $\sin\phi\,\sin\grave{\theta}$

48 Figure (1) represents the incidence of a light ray in air onto the boundary surface of medium ①, if medium ① is changed with another medium ② as shown in figure (2), then ............ .

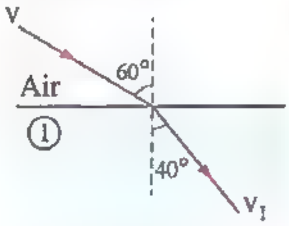



Figure (1)

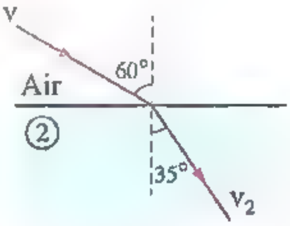
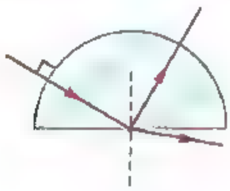
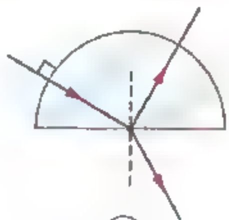


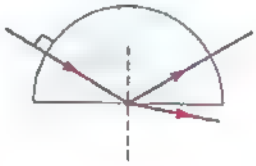

Figure (2)

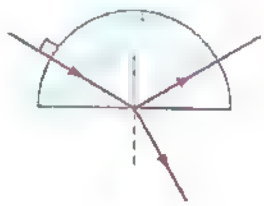
| | The relation between the refractive indices of the two media | The relation between the speeds of light in the two media |
|---|---|---|
| ⓐ | $n_1 > n_2$ | $v_1 > v_2$ |
| ⓑ | $n_1 > n_2$ | $v_1 < v_2$ |
| ⓒ | $n_1 < n_2$ | $v_1 > v_2$ |
| ⓓ | $n_1 < n_2$ | $v_1 < v_2$ |

49 A ray of red light is incident perpendicular to the spherical surface of a semi sphere, so which of the following figures represents the correct path of the light ray?


ⓐ


ⓑ


ⓒ


ⓓ

50 Each of the following figures represents the path of a light ray when it travels between two media,

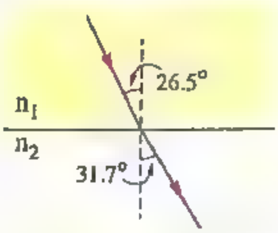



Figure (1)

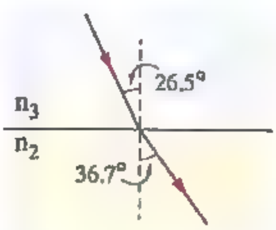



Figure (2)

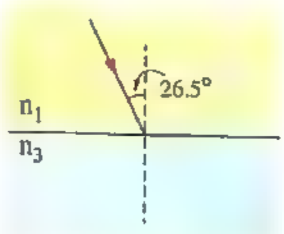
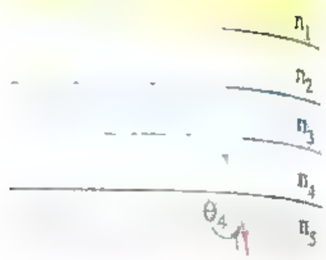



Figure (3)

so using the angles represented in these figures, the angle of reflection of the light ray in figure (3) equals ............ .

ⓐ 41.7° ⓑ 30.5° ⓒ 23.1° ⓓ 18.6°

**51** ✻ The opposite figure shows a light ray falling on successive parallel layers of transparent media of different refractive indices, so:




(i) The ratio $\frac{\sin \phi_1}{\sin \theta_4}$ depends on refractive indices ............ .

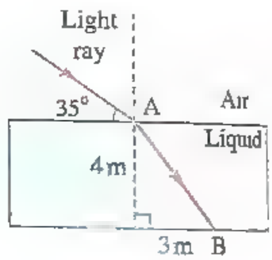
(a) $n_1, n_5$ only (b) $n_2, n_3, n_4$ only

(c) $n_1, n_2, n_3, n_4, n_5$ (d) $n_1, n_2$ only

(ii) The medium in which the speed of light is the greatest is ............ .

(a) 1 (b) 2 (c) 3 (d) 4

**52** ✻ The opposite figure represents a light ray travelling from air through a layer of liquid of thickness 4 m, so if the speed of light in air equals $3 \times 10^8$ m/s, then :




(i) The refractive index of liquid equals ............ .

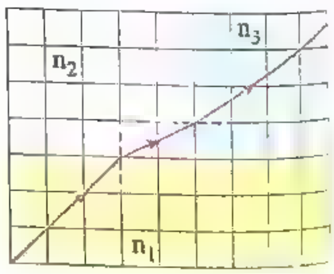
(a) 1.53 (b) 1.49

(c) 1.42 (d) 1.37

(ii) The time taken by the light ray to travel from A to B equals ............ .

(a) $2.28 \times 10^{-10}$ s (b) $114 \times 10^{-8}$ s (c) $2.28 \times 10^{-8}$ s (d) $114 \times 10^{-10}$ s

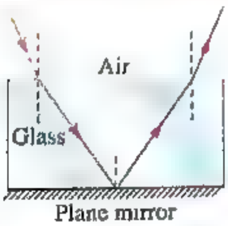
**53** ✻ The opposite figure represents with a definite drawing scale the path of a light ray through three transparent media of refractive indices $n_1$, $n_2$ and $n_3$, so the correct order of refractive index values is ............



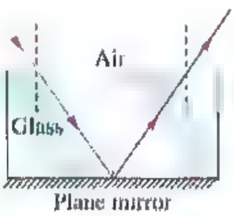

(a) $n_1 > n_2 > n_3$ (b) $n_3 > n_1 > n_2$

(c) $n_2 > n_1 > n_3$ (d) $n_2 > n_3 > n_1$

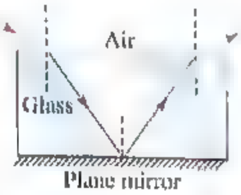
**54** A monochromatic light ray falls from air into a cuboid of glass which is placed above a plane mirror, so the correct path of the ray is represented in figure ............ .



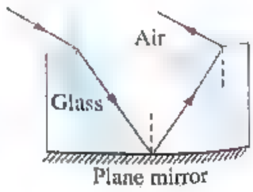

(a)




(b)




(c)




(d)

55 The opposite figure shows a light ray travelling through three different media, so the relation among :


(i) The absolute refractive indices of these media is demonstrat[illegible]

ⓐ $n_3 > n$ [illegible]

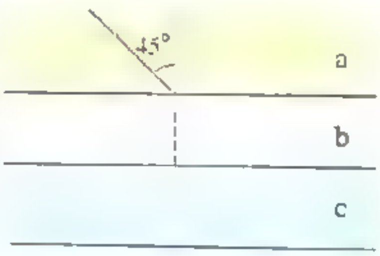
ⓒ $n_2 > n_1 > n_3$ ⓓ [illegible]

(ii) The speeds of light in the three media is ..........

ⓐ $v_1 > v_2 > v_3$ ⓑ $v_2 < v_1 < v_3$

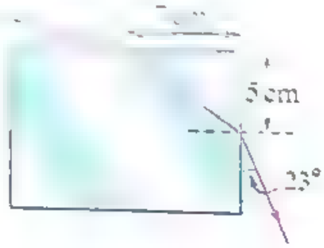
ⓒ $v_1 > v_3 > v_2$ ⓓ $v_3 < v_1 < v_2$

56 ✱ A light ray has fallen to pass through three transparent media a, b and c as in the opposite figure. If the speed of light in medium a is 1.4 of its speed in medium b, then the angle of incidence on the boundary surface between the two media b and c equals ............ .




ⓐ 30.34° ⓑ 34.30° ⓒ 59.7° ⓓ 81.87°

57 ✱ The opposite figure shows the path of a light ray through a glass cuboid, then the refractive index of glass is ............ .




ⓐ 1.63 ⓑ 1.67

ⓒ 1.41 ⓓ 1.58

58 A light beam passes perpendicular into a glass sheet of thickness d and refractive index n, so if the speed of light in empty space is c, the time interval taken by the light to traverse the thickness of the sheet equals ............ .

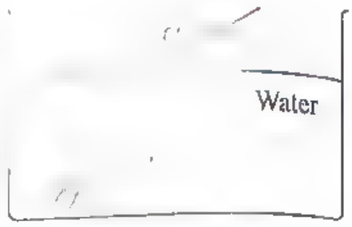
ⓐ $\frac{nd}{c}$ ⓑ $\frac{d}{nc}$ ⓒ $\frac{dc}{n}$ ⓓ $\frac{c}{nd}$

59 If the absolute refractive index of water is 1.33, then the time taken by light to cover a distance of 20 m in water equals ............ .

(Knowing that: The speed of light in air = $3 \times 10^8$ m/s)

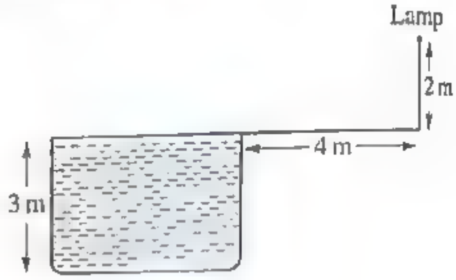
ⓐ $8.87 \times 10^{-8}$ s ⓑ $1.13 \times 10^{-7}$ s ⓒ $2.25 \times 10^{-8}$ s ⓓ $4.52 \times 10^{-9}$ s

(60) In the opposite figure, a light ray passes from water to air to emerge with an angle α, so if another transparent immiscible liquid whose density is lower than water is poured slowly above water so that it floats on the surface of water, the angle of emergence of the light ray to air ............ .




ⓐ will increase
ⓑ will decrease
ⓒ may increase or decrease
ⓓ won't change

(61) ✻ A swimming pool of depth 3 m is filled completely with water of refractive index $\frac{4}{3}$. To light the bottom of the swimming pool, a lamppost of height 2 m is installed at a distance 4 m from the edge of the swimming pool. The length of the dark part at the bottom of the swimming pool is ............ .



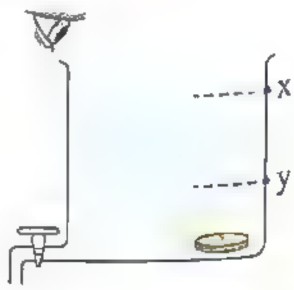

ⓐ 2 m
ⓑ 1.07 m
ⓒ 2.71 m
ⓓ 3.32 m

(62) A light ray fell at an angle of incidence 30° on the boundary surface between the air and the cornea of the eye of a swimmer. If the swimmer dove under the water surface, then the angle of incidence of the light ray in water that makes it get refracted as if the swimmer was in air is ............ .

(Where: The refractive index of water = 1.33, the refractive index of cornea = 1.4)

ⓐ 19.82°
ⓑ 22.08°
ⓒ 22.92°
ⓓ 29.9°

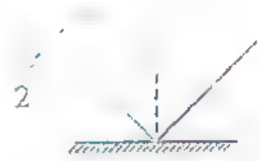
(63) The opposite figure shows a man looking constantly at a metal coin that is placed at the bottom of a container filled with water up to level x, hence the coin seems to him at specific position (a). When water is let to spill out gradually from the container till the surface of water becomes at level y, the man will see the image of the coin ............ .




ⓐ rising up gradually
ⓑ descending gradually
ⓒ stable at the bottom of the container
ⓓ remained stable at its level (a)

## Essay questions

**1** The opposite figure shows the reflection of a light ray. If the angle of incidence is increased, does the reflected ray change its path? And if it does, in which direction it will be changed? **Explain your answer.**




**2** The opposite figure shows a light ray which is falling perpendicularly from air onto the surface of water. **Find the value of the angle of refraction with explaining your answer.**


**3** A light ray travelled from a medium of refractive index $n_1$ to another medium of refractive index $n_2$. **Show by drawings the path of the light ray through the two media if:**

(a) $n_2 < n_1$ (b) $n_2 > n_1$

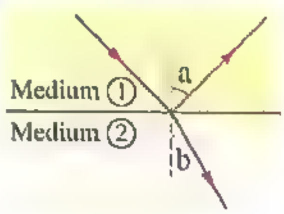
**4** **Explain the following statements:**

(1) It is easier to see your reflected image on the glass of a window from the inside of a lighted room at night when the outside is dark than seeing your image at daytime when there is light outside.

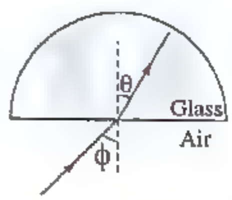
(2) The absolute refractive index for any medium is always greater than one however the relative refractive index may be less or greater than one.

**5** When a wave of light moves from medium (1) to another medium (2) for which the ratio between the absolute refractive indices is $\frac{n_2}{n_1} > 1$, **what happens to** each of the frequency, the wavelength and the speed of the wave?

**6** The opposite figure shows the transmission of a light wave between two media ① and ②, **what will happen to** each of angle a and angle b if the angle of incidence increases?



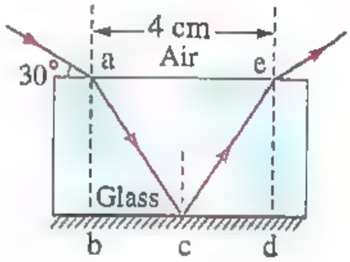

**7** The opposite figure shows a red light ray falling on a semi-circular prism. **Will** the angle of refraction change if a blue light ray is used instead of the red light? **Explain your answer.**



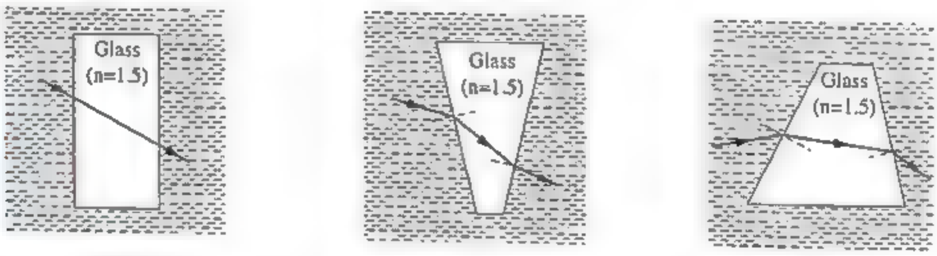
**8** The opposite figure shows the path of a light ray falling from air on a glass block.
**Prove that:** $\phi_1 = \theta_2$


**9** In the opposite figure, two light rays intersect at a point on a vertical screen. If a glass plate is put in front of the screen in the path of the two rays, **will** the two rays intersect on the screen? **Explain your answer.**


**10** The opposite figure represents the path of a light ray which is incident on a glass cuboid of refractive index $\sqrt{3}$ that is placed above a plane mirror until it emerges from the cuboid to the air, **what** is the thickness of the cuboid (ab or ed)?




**11** **Study the following figures and answer:**

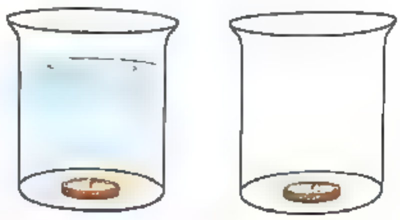



(1) (2) (3)

**Which of these figures represents the falling of a light ray from a liquid having the following refractive indices?**

(a) 1.5 (b) 1.3 (c) 1.6

**12** In the opposite figure, two metal coins are put in two cups such that one coin is put in an opaque cup containing water and the other in a similar empty cup, so if you look at the two coins with a certain inclination angle, you will see a part of the coin which is put in the cup containing water and not see the coin in the empty cup, **explain that.**

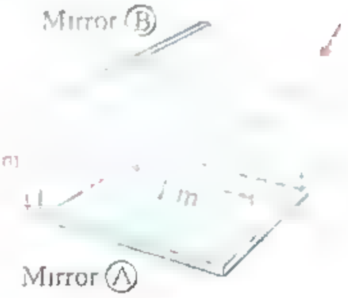


# New Types of questions

Understand  Apply  Higher Order Thinking Skills

**First : Choose two correct answers in each of the following**

**1** The opposite figure represents two perpendicular plane mirrors (A) and (B). A light ray is incident with an ang [illegible] mirror (A), so the ray w [illegible]




(a) be reflected from mirror (A) with an angle of reflection 30°
(b) be incident on mirror (B) with an angle of incidence 30°
(c) be incident on mirror (B) with an angle of incidence 60°
(d) be reflected from mirror (B) with an angle of reflection 90°
(e) not be incident on mirror (B)

---

**2** A light that has a speed $v_1$, wavelength $\lambda_1$ and frequency $\upsilon_1$ while travelling in a medium of refractive index $n_1$ moves to another medium of refractive index $n_2$, so if $n_1 < n_2$, ..... .......

(a) its speed becomes $\frac{n_1}{n_2} v_1$
(b) its frequency becomes $\frac{n_1}{n_2} \upsilon_1$
(c) its wavelength becomes $\frac{n_1}{n_2} \lambda_1$
(d) its speed becomes $\frac{n_2}{n_1} v_1$
(e) its wavelength becomes $\frac{n_2}{n_1} \lambda_1$

**Second: Put in front of each of the following sentences the suitable [illegible] phenomenon that represents it:**

**(1) Reflection**  **(2) Refraction**

(1) In which the speed of light changes (.......)

(2) Through which the path of the ray remains in the same medium. (.......)

(3) In which the angle between the ray that has suffered from this phenomenon and the normal on the surface is always equal to the angle of incidence of the ray of that surface. (.......)

(4) In which the angle between the ray that has suffered from this phenomenon and the normal on the surface sometimes equals the angle of incidence of the ray of that surface. (.......)

(5) In which the path of the light ray may not change. (.......)

(6) In which the path of the light ray may be changed by 180°. (.......)

Why CDs reflect rainbow colors?

Chapter 2

Lesson Two

# Properties of Light
## (Interference and Diffraction)

### Interference of waves

The phenomenon of wave interference occurs when two waves that are propagating in the same medium and have been produced from two coherent sources (sources that have the same frequency, wavelength and phase) overlap (principle of superposition) leading to;

**1** **A reinforcement in the intensity of the two waves at some positions "constructive interference"**

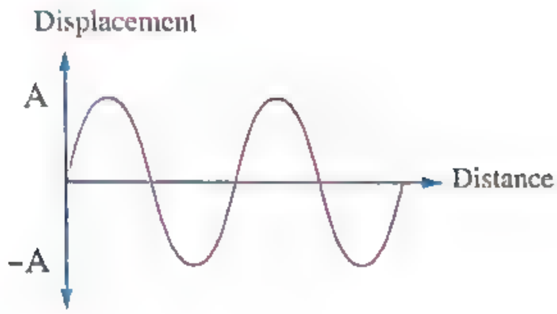
**2** **A weakness in the intensity of the two waves at some other positions "destructive interference"**

**As a result of**

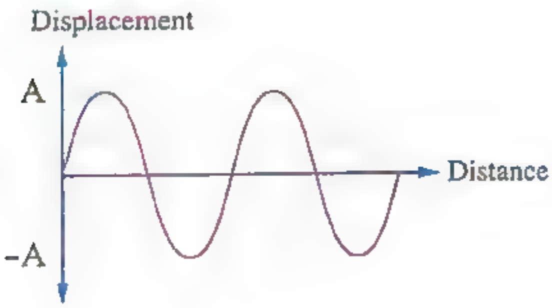
| Constructive interference | Destructive interference |
|---|---|
| The overlap (superposition) of a crest from one wave with a crest from the other wave or a trough from one wave with a trough from the other wave. | The overlap (superposition) of a crest from one wave with a trough from the other wave. |

**This can be represented graphically as fol**

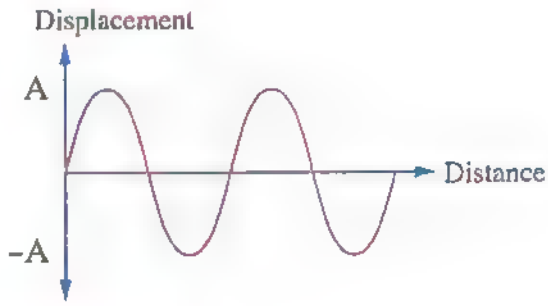
Wave 1



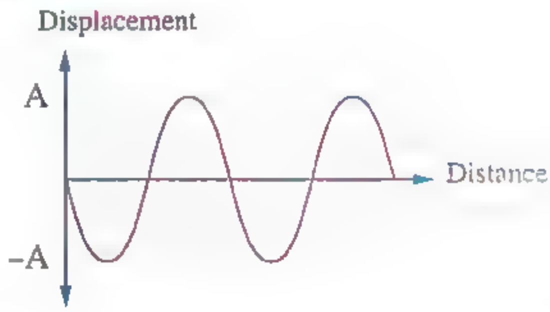

Wave 2



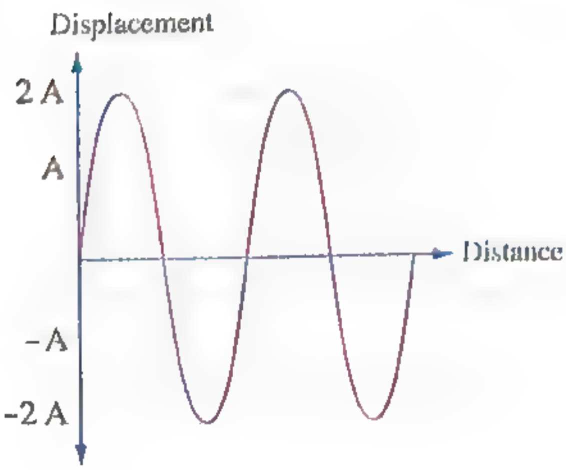

Wave 1

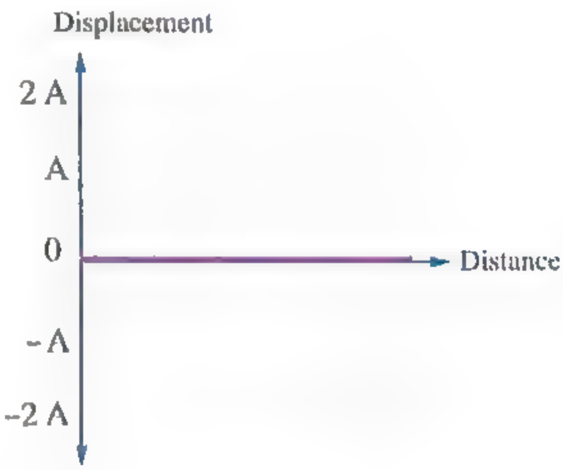



Wave 2




**Resultant wave**



# Fourth Light interference

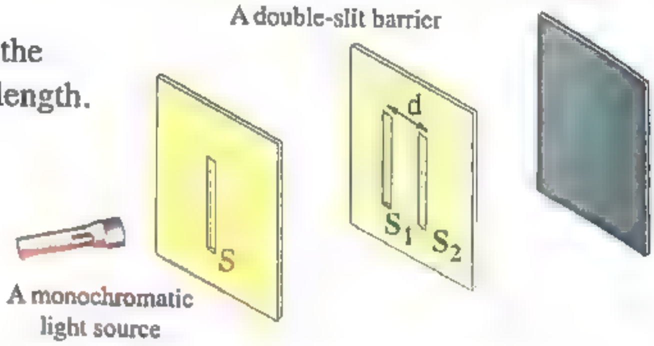
- To study the interference of light, we carry out the following experiment.

## Thomas Young's double-slit Experiment

### Objectives:

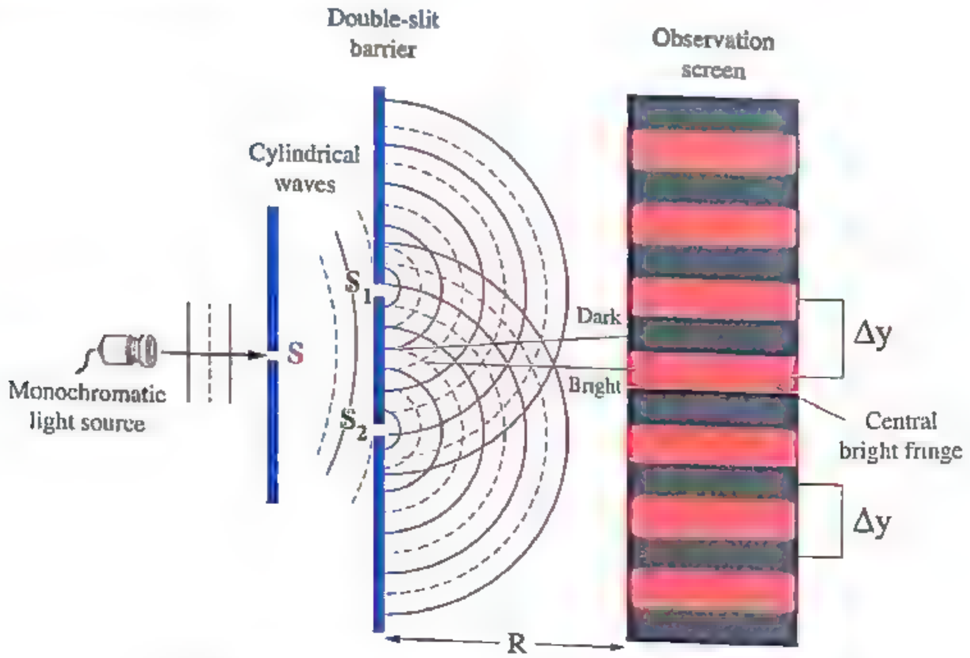
1. Proving the wave nature of light.
2. Investigating the phenomenon of light interference.
3. Determining the wavelength of a monochromatic (single wavelength) light.

### Apparatus:




- **A monochromatic light source** so that the overlapping waves have the same wavelength.
- **A barrier with a rectangular** narrow slit "S" positioned at equal distances from both slits $S_1$, $S_2$ and at an appropriate distance from the light source.
- **A barrier with two rectangular narrow slits** ($S_1$ **and** $S_2$) to act as a double-slit separated by a distance d.
- **A screen** to receive the interference pattern.

### Steps, observations and conclusions:




*Schematic diagram of Young's double-slit experiment*

1. When turning on the light source, the light waves pass from slit S in the form of cylindrical waves, where:

- The continuous) curves represent wave crests.

- The dashed } curves represent wave troughs.

2. The two slits ($S_1$, $S_2$) are adjusted, so when the light waves reach them, they will be at the same cylindrical **wavefront,** so they act as two **coherent sources,** *i.e.* They produce two coherent waves having the same frequency, amplitude and phase.

3. The two waves from $S_1$ and $S_2$ propagate beyond the double slit barrier and when they reach the last screen, they interfere with each other and give a pattern of interference (as shown in the previous figure) and this phenomenon is known as the **interference of light** and it can be defined as follows:

**Interference pattern :**
It is a pattern of bright fringes (maxima) punctuated with dark fringes (minima) resulted from the superposition of the light waves that are produced from two coherent sources.

**Interference of light :**
It is the phenomenon of superposition of the light waves that are produced from two coherent sources causing reinforcement in light intensity in some positions (bright fringes) and weakness in light intensity in other positions (dark fringes).

4. Measure the distance between the centers of two successive fringes ($\Delta y$) of the same kind (bright or dark), hence with knowing each of $\Delta y$, R and d, the wavelength of the used light can be determined from the relation: $\Delta y = \frac{\lambda R}{d}$

Where: ($\lambda$) is the wavelength of the used light, (R) is the distance between the double-slit barrier and the observation screen and (d) is the distance between the two slits.

**As studying Young's double-slit experiment, we find that:**

(1) Conditions for the occurrence of light interference:

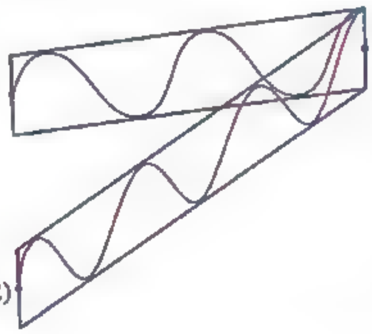
- The used light source must be monochromatic.
- Slit S must be at equal distances from the two slits $S_1$, $S_2$ for making the double-slit work as two coherent light sources.

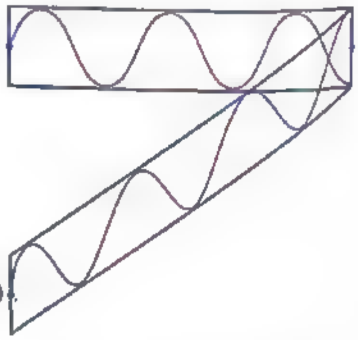
**(2) The interference of waves is of two types:**

| | Constructive interference | Destructive interference |
|---|---|---|
| **It produces** | Reinforcement in the intensity of the light in some regions (bright fringes) as a result of the overlapping of a crest of one wave with a crest of another wave or a trough of one wave with a trough of another wave. | Weakness in the intensity of the light in some regions (dark fringes) as a result of the overlapping of a crest of one wave with a trough of another wave. |
| **Its condition** | The path difference of the two interfered waves = $m\lambda$ | The path difference of the two interfered waves = $(m + \frac{1}{2})\lambda$ |

Where: m is the order of the fringe which is an integer number ( 0, 1, 2, ...).

**Representation**



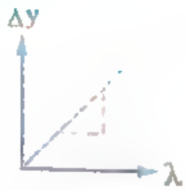




7. The two waves that have equal path lengths give the central fringe which is always a bright fringe because the path difference at this fringe equals zero, so the interference becomes constructive.

## The factors affecting The distance [illegible] successive fringes of the same kind

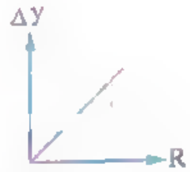
**1** The wavelength of the used light "directly proportional".

$$\text{Slope} = \frac{\Delta(\Delta y)}{\Delta\lambda} = \frac{R}{d}$$




**2** The distance between the observation screen and the double-slit barrier "directly proportional"

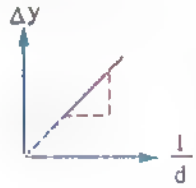
$$\text{Slope} = \frac{\Delta(\Delta y)}{\Delta R} = \frac{\lambda}{d}$$




$$\Delta y = \frac{\lambda R}{d}$$

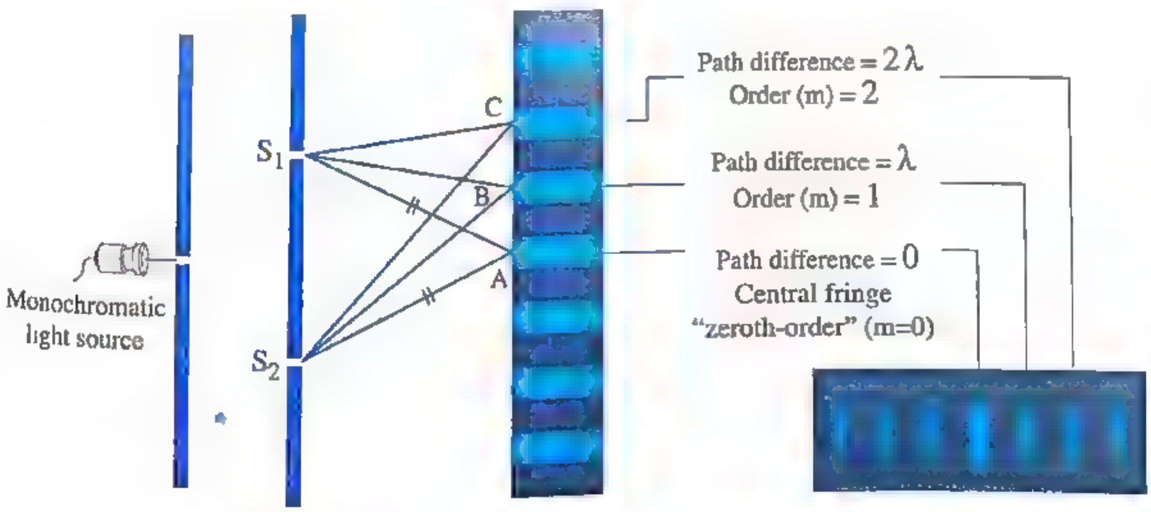
**3** The distance between the two slits "inversely proportional".

$$\text{Slope} = \frac{\Delta(\Delta y)}{\Delta\left(\frac{1}{d}\right)} = \lambda R$$




## Note :

(1) In the following diagram:




• **Point A represents the center of the central fringe (always bright), at which:**

The path length of the first wave resulted from slit $S_1$ = The path length of the second wave resulted from slit $S_2$

• Point B represents the center of the first bright fringe, at which:

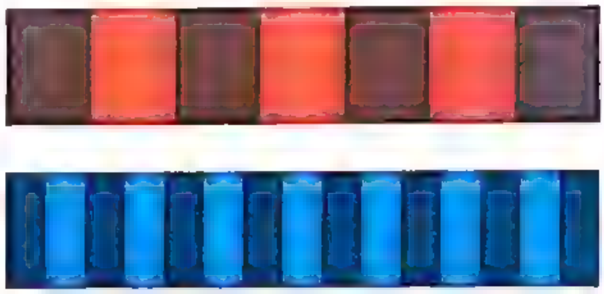
The path length of the first wave resulted from slit $S_1$ < The path length of the second wave resulted from slit $S_2$ by a value of $\lambda$

• Point C represents the center of the second bright fringe, at which:

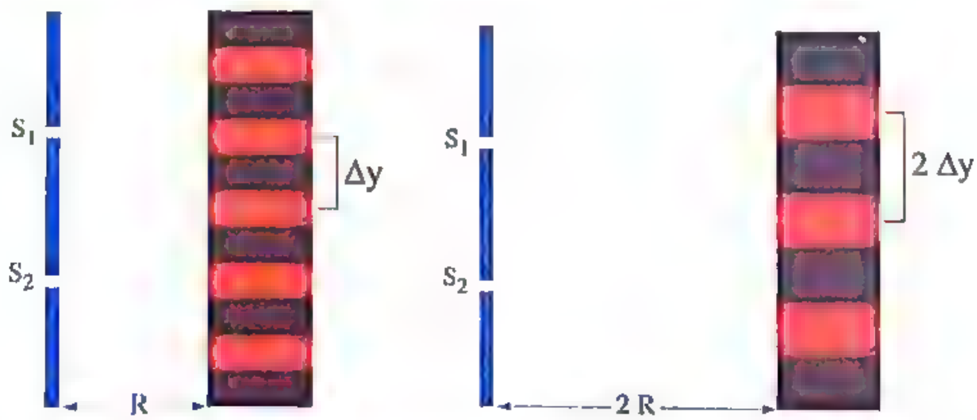
The path length of the first wave resulted from slit $S_1$ < The path length of the second wave resulted from slit $S_2$ by a value of $2\lambda$

**And consequently, the path difference between two overlapping waves can be determined at the centers of the rest of interference fringes.**

(2) In Young's double-slit experiment, it is preferable to use a light of relatively long wavelength to make the distance between the interference fringes relatively large, hence the interference pattern becomes easier to be observed as shown in the following figure where $\lambda_b < \lambda_r$.



(3) When increasing the distance between the double-slit barrier and the observation screen (R), the distance between the interference fringes increases according to the relation $\left(\Delta y = \frac{\lambda R}{d}\right)$ as represented in the following figure:



## Example 1

*In the double-slit experiment; if the distance between the two narrow rectangular slits was 0.15 mm, the distance between the double-slit barrier and the observation screen was 75 cm and the distance between the centers of two successive bright fringes was 0.3 cm, calculate the wavelength of the used monochromatic light source.*

### Solution

$d = 0.15$ mm | $R = 75$ cm | $\Delta y = 0.3$ cm | $\lambda = ?$

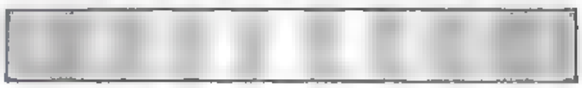
$$\Delta y = \frac{\lambda R}{d}$$

$$\lambda = \frac{d\Delta y}{R} = \frac{0.15 \times 10^{-3} \times 0.3 \times 10^{-2}}{75 \times 10^{-2}} = 6 \times 10^{-7}\ \text{m} = 0.6\ \mu\text{m} = 6000\ \text{Å}$$

**What if** the observation screen is displaced away from the double-slit barrier, **what will happen to** the distance between any two successive dark fringes?

## Example 2

*The opposite figure represents the interference pattern of Young's experiment which was conducted with a light of wavelength 5000 Å and an observation screen at distance 120 cm from the double-slit. If the distance between the central fringe (0) and the fourth bright fringe (4) was 0.8 cm, calculate the distance between the two slits.*




### Solution

$x = 0.8$ cm | $N = 4$ | $\lambda = 5000$ Å | $R = 120$ cm | $d = ?$

**Clue**

*To find the distance between the centers of two consecutive fringes of the same type ($\Delta y$) using the distance ($x$) between any two fringes we use the following relation:*

$$\Delta y = \frac{x\ (\textit{Total distance})}{N\ (\textit{Number of fringes})}$$

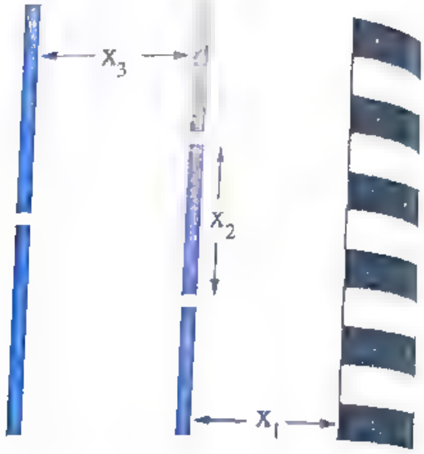
$$\Delta y = \frac{x}{N} = \frac{0.8 \times 10^{-2}}{4} = 2 \times 10^{-3}\ \text{m}$$

$$\Delta y = \frac{\lambda R}{d}$$

$$d = \frac{\lambda R}{\Delta y} = \frac{5000 \times 10^{-10} \times 120 \times 10^{-2}}{2 \times 10^{-3}} = 3 \times 10^{-4}\ \text{m}$$

**Example 3**

*The opposite figure represents a setup of the double-slit experiment, which of the distances that are drawn in the figure has to be reduced to make the interference pattern become more obvious?*




ⓐ $x_1$ ⓑ $x_2$

ⓒ $x_3$ ⓓ $x_1$, $x_2$

**Solution**

By decreasing the distance between the two rectangular narrow slits ($d = x_2$) and according to the relation; $\left(\Delta y = \frac{\lambda R}{d}\right)$, the distances between the centers of every two identical successive fringes ($\Delta y$) increases, hence the fringes become easier to be seen.

∴ **The correct choice is ⓑ.**

## Test yourself

Answers

**1** ✱ A monochromatic light of wavelength $66 \times 10^{-8}$ m fell on two slits of separation distance $11 \times 10^{-4}$ m, so interference fringes were formed on an observation screen which was at a distance 1 m from the double-slit barrier.

**Calculate** the distance between the centers of two successive fringes of the same type.

..............................................................................................................

..............................................................................................................

..............................................................................................................

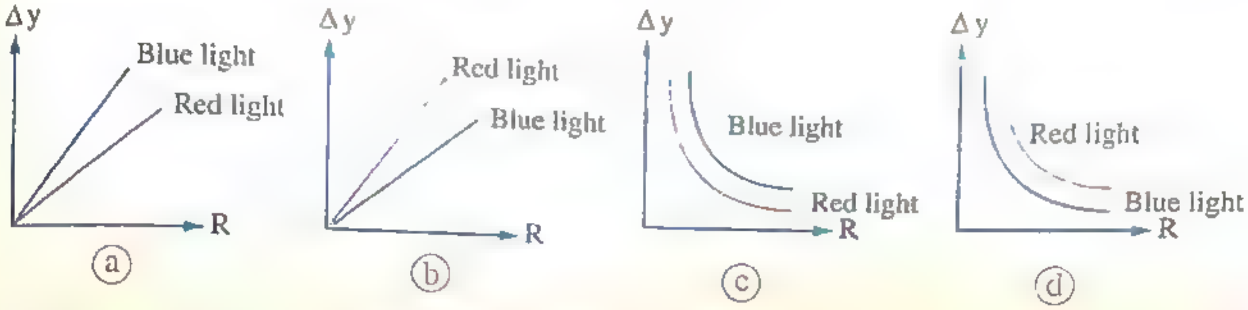
**2 Choose the correct answer:**

(1) The opposite figure represents the interference pattern obtained in a double-slit experiment when using a light of wavelength λ, so if a light of wavelength 1.5 λ is used, the distance between the centers of the central fringe and the first bright fringe becomes ............ .


ⓐ 0.5 mm ⓑ 0.75 mm

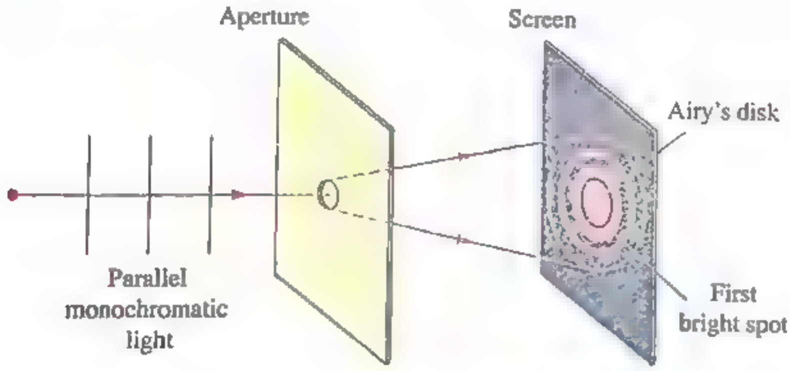
ⓒ 1.25 mm ⓓ 1.5 mm

(2) Young's double-slit experiment has been conducted twice, one time using a red light and the other using blue light, while in both times the distance between the double-slit barrier and the observation screen was being changed, which of the following graphs represents the variation of the distance between the centers of two identical successive fringes ($\Delta y$) versus the distance between the double-slit barrier and the observation screen (R) in both cases?




## Fifth Light diffraction

When a monochromatic light is incident on a small aperture of a barrier or a circular aperture whose size is small compared to the wavelength of the incident light, a bright spot of light which is called Airy's disk appears at the center surrounded by alternated progressively fainter bright and dark rings. This phenomenon happens as a result of light diffraction.




*Diffraction on a circular aperture*

**What happens can be explained as follows:**

When monochromatic light waves fall on a sharp edge or on a circular aperture of a barrier whose size is small compared to the wavelength of the incident light:

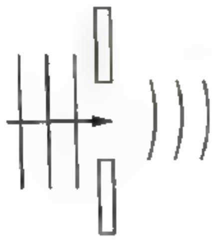
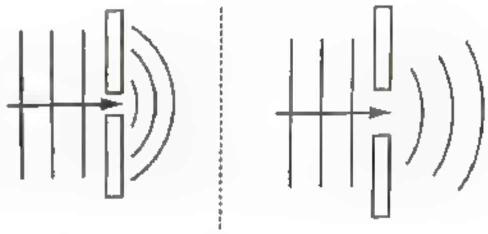
- They change their direction of propagation (diffract).
- Each point on the wavefront of the wave passing through the aperture acts as a secondary light source that forms waves of the same wavelength and phase.
- These waves interfere (superpose) with each other behind the aperture giving **diffraction fringes**.

**Diffraction fringes pattern**

It is a pattern of alternate bright and dark regions produced due to the superposition of the diffracted light waves as passing from an aperture of a very small size or falling on a sharp edge.

### ⊙ The condition of a clear appearance of light diffraction:

The wavelength of the light wave has to be close in size to the dimensions of the aperture, so if the aperture size is:

| much larger than the wavelength of light | comparable to the wavelength of light |
| --- | --- |
|  |  |
| The diffraction doesn't appear. | The diffraction appears and becomes more clearer by decreasing the aperture size. |

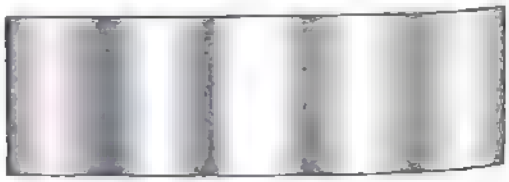
**➲ From the previous, light diffraction can be defined as follows:**

**Diffraction of light**

It is the phenomenon of changing the direction of light waves propagation through the same medium when they pass through a very narrow aperture or fall on a sharp edge in which the superposition of waves leads to the formation of bright and dark fringes.

## Notes:

1. The shape of the diffraction fringes depends on the shape of the narrow slit on which light is incident, so when light falls on a rectangular narrow aperture, it suffers diffraction and the diffraction fringes appear as a pattern having a central wide bright fringe surrounded laterally with progressively fainter and narrower distributed bright fringes punctuated with dark fringes as shown in the figure.



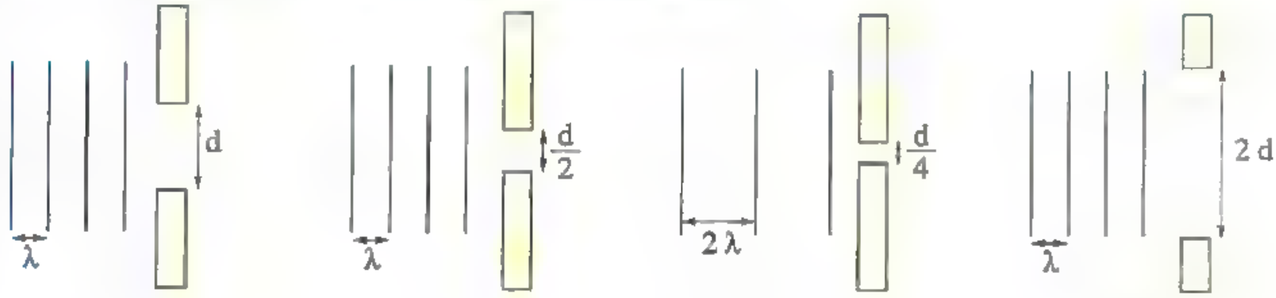
2. **The range of wavelengths of visible light extends from 400 nm to 700 nm which are very short wavelengths so that light diffraction doesn't appear in our daily life** because visible light needs very small aperture sizes for the appearance of light diffraction patterns.
3. **From the study of light interference and light diffraction phenomena, it was found that there is no big difference between the light interference model and light diffraction model** because each of them is a wave phenomenon which results from the superposition of waves.

## Enrichment information

A diffraction grating is an optical component made of a sheet having a large number of evenly spaced parallel slits that reaches 10000 slits separated by distances that could reach $10^{-6}$ m which produce a diffraction pattern.

## Example

*In each of the following figures a wave encounters a narrow slit, so in which of these cases the most obvious diffraction pattern appears?*




ⓐ ⓑ ⓒ ⓓ

### Solution

As the size of the slit through which the wave passes decreases compared to the wavelength, diffraction becomes more obvious.

∴ **The correct choice is ⓒ.**

## 2 Test yourself

**Choose the correct answer:**

Which of the following figures shows the pattern of light diffraction through a circular aperture?

(a) (b) (c) (d)

➲ From the previous, we can compare between interference and diffraction as follows:

| Interference | Diffraction |
|---|---|
| It appears when using a double-slit. | It appears when using a single narrow slit. |
| Bright and dark fringes that are equally spaced are formed. | Central wider bright fringe surrounded by less wide bright fringes are formed. |
| Light intensities at the centers of the bright fringes are equal. | Light intensities at the centers of the bright fringes get dimmer as we get away at the two sides from the central fringe. |

➲ The phenomena of reflection, refraction, interference and diffraction of light waves can be summed up as follows:

| | | |
|---|---|---|
| Reflection | Scientific concept | The bouncing of light waves in the same medium when they meet a reflecting surface. |
| | Occurrence | At the reflecting surface in the same medium. |
| | Condition | The light waves fall on a reflecting surface. |
| Refraction | Scientific concept | The change in the direction of light path when it passes the separating surface between two transparent media which are different in the optical density. |
| | Occurrence | At the boundary surface between two transparent media which are different in the optical density. |
| | Condition | The two transparent media have different optical densities. |
| Interference | Scientific concept | The superposition of light waves produced from two coherent sources, producing reinforcement (bright fringes) in some regions and weakness (dark fringes) in other regions. |
| | Occurrence | In the same medium when the light encounters a double-slit. |
| | Condition | - Using a monochromatic light source.<br>- Slit S must be at equal distances from the other two slits ($S_1$, $S_2$), hence the double-slit works as two coherent light sources. |

| | | |
|---|---|---|
| **Diffraction** | Scientific concept | The change in the direction of the waves path in the same medium when passing through a narrow slit or an aperture whose dimensions are comparable to the wavelength of the light waves leading to the superposition of waves and the formation of bright fringes and dark fringes. |
| | **Occurrence** | At a slit or a sharp edge in the same medium. |
| | **Condition** | The size of the slit must be near in size to the wavelength of the light. |

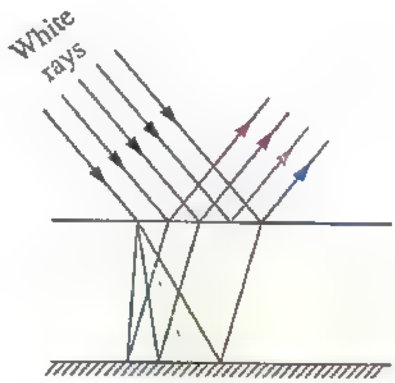
**From the previous, the wave properties of light can be summarized as the following:**

1. Light rays propagate in straight lines in the homogeneous medium.
2. They reflect when they fall on a reflecting surface, according to the laws of reflection.
3. They refract when they travel between two transparent media of different optical densities, according to the laws of refraction.
4. Light waves interfere when they meet other waves that have the same frequency, amplitude and phase producing regions of constructive interference (maxima) and regions of destructive interference (minima).
5. They diffract in the same medium when they pass through slits or by sharp edges that have dimensions near in size to the wavelength of the incident light waves.

### Learn for leisure

**Why do CDs reflect rainbow colors?**

- CDs are made of a reflecting surface coated by a transparent layer (thin film).
- White light is composed of a range of different wavelengths (different colors).
- When white light falls on a CD, each color refracts with a different angle in the thin film then they reflect on the reflecting surface of the CD.
- When the rays of light reach the surface of the thin film they interfere with the white rays that are reflecting from the surface of the thin film.




- Each color interfere with its similar color at the surface of the thin film and that leads to the formation of rainbow colors on the CD.
- The same phenomenon happens in water and soap bubbles.

Chapter 2

Questions on Lesson Two

# Properties of Light

## (Interference and Diffraction)

The questions signed by ✳ are answered in detail.

Understand  Apply  Higher Order Thinking Skills

To watch videos of how to solve questions use the App

معاك

Interactive test

## First Multiple choice questions

### Light interference

1. The interference of light, is resulted due to ............. .
   - (a) the bouncing of waves
   - (b) the deviation of waves
   - (c) the superposition of waves
   - (d) the change of the speed of light

2. The double-slit in Young's double-slit experiment works as two coherent light sources, in which coherence means that the two waves formed from the double-slit have the same ............. .
   - (a) phase
   - (b) amplitude
   - (c) speed
   - (d) direction

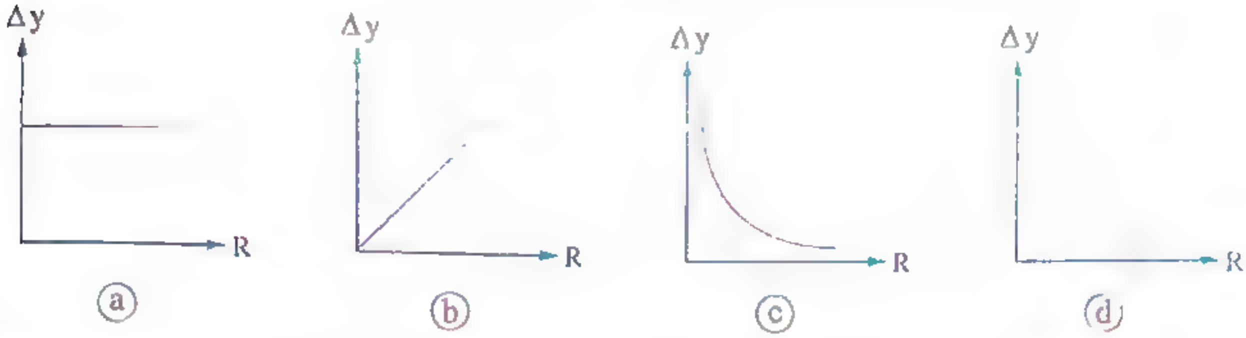
3. In Young's double-slit experiment, the widths of interference fringes don't depend on ............. .
   - (a) the distance between the two coherent sources
   - (b) the distance between the double-slit barrier and the observation screen
   - (c) the wavelength of the light emitted from the source
   - (d) the distance between the double-slit barrier and the light source

4. In Young's double-slit experiment, the interference fringes widths increase when ............. .
   - (a) the distance between the double-slit and the observation screen decreases
   - (b) the distance between the double-slit and the observation screen increases
   - (c) the distance between the two slits increases
   - (d) the wavelength of the used monochromatic light decreases

5. Which of the following figures represents the interference pattern formed in a Young's double-slit experiment?

(a) (b) (c) (d)

**6** In Young's double-slit experiment, which of the following figures, represents the graph of the distance between the center of the central fringe and the center of its following bright fringe ($\Delta y$) versus the distance between the double slit barrier and the screen (R)?



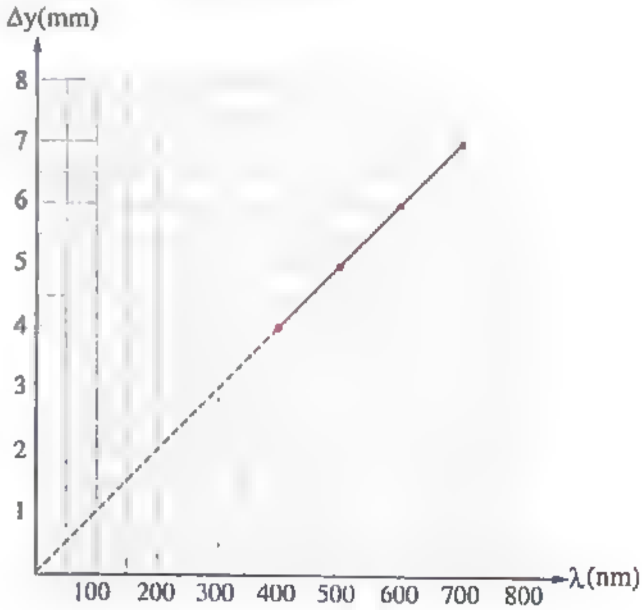

**7** In a Young's double-slit experiment, when increasing the intensity of the used light, the distance between the center of the central fringe and that of the first dark fringe .............. .

ⓐ increases ⓑ decreases ⓒ vanishes ⓓ doesn't change

**8** In a Young's double-slit experiment, the separation distance between the two slits was $10^{-4}$ m and the distance between two consecutive fringes of the same type was found to be 3.75 mm when they appeared on an observation screen at a distance 0.75 m from the two slits, so the wavelength of the used light equals .............. .

ⓐ 5000 Å ⓑ 5400 Å ⓒ 6000 Å ⓓ 6400 Å

**9** ✻ The opposite graph shows the variation of the distance between the center of the central bright fringe and the center of the first bright fringe ($\Delta y$) versus the wavelength of the used light in a Young's double-slit experiment ($\lambda$), so if the distance between the observation screen and the double-slit barrier is 1 m, the distance between the two slits (d) equals .............. .




ⓐ $10^4$ m

ⓑ $10^{-4}$ m

ⓒ $10^2$ m

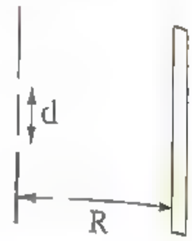
ⓓ $10^{-2}$ m

**10** ✳ In a Young's double-slit experiment, if the distance between the two coherent sources was 1.6 mm where the interference fringes were formed on a screen at a distance of 60 cm from them such that the center of the third bright fringe was at 0.6 mm from the center of the central fringe, then the frequency of the used light equals ............ .

(Given that: the speed of light in air = $3 \times 10^8$ m/s)

ⓐ $4.08 \times 10^{16}$ Hz ⓑ $5.63 \times 10^{14}$ Hz ⓒ $4.74 \times 10^{12}$ Hz ⓓ $7.08 \times 10^{11}$ Hz

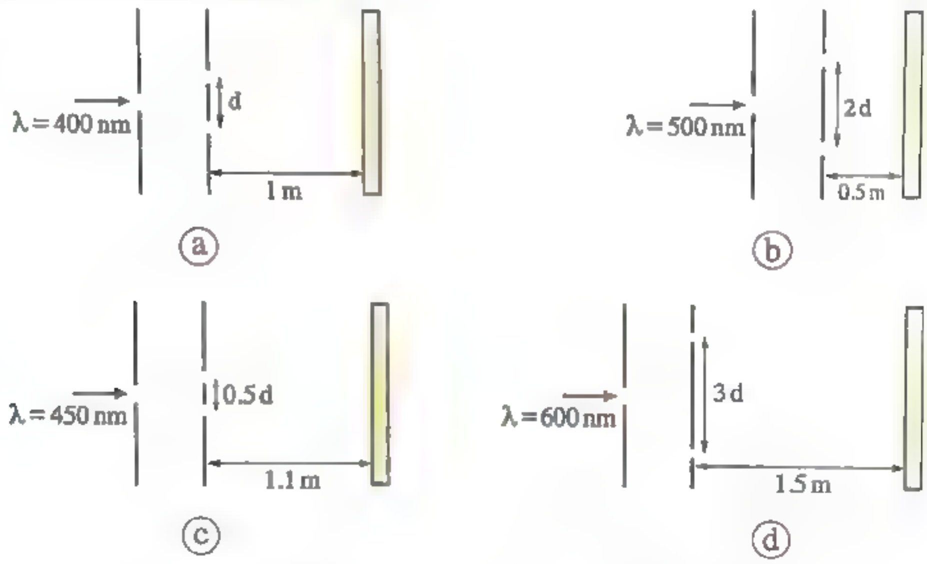
**11** In Young's double-slit experiment represented in the opposite figure, if $R = 10^4$ d, then ............



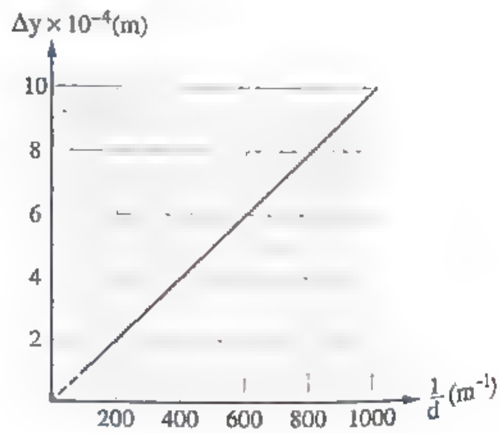

ⓐ $\Delta y = \lambda$ ⓑ $\Delta y = 10^4 \lambda$

ⓒ $\Delta y = 10^{-4} \lambda$ ⓓ $\Delta y = \frac{\lambda}{10}$

**12** Which of the following diagrams of Young's double-slit apparatus will yield the best noticeable interference fringes?




**13** ✳ The opposite graph represents the variation of the distance between two bright consecutive fringes ($\Delta y$) versus the reciprocal of the distance between the double slits $\left(\frac{1}{d}\right)$, if the distance between the double slit and the observation screen is 2 m, then the wavelength of the used light equals ............ .



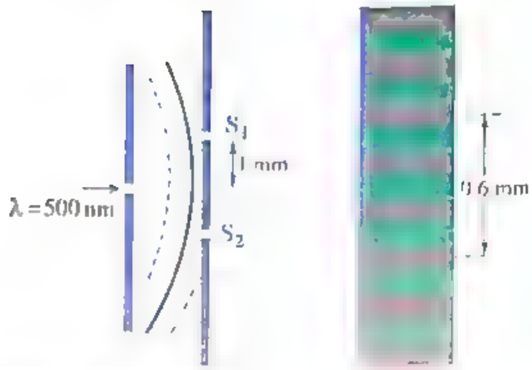

ⓐ $5 \times 10^{-3}$ m

ⓑ $2 \times 10^{-6}$ m

ⓒ $10^{-6}$ m

ⓓ $5 \times 10^{-7}$ m

14 ✻ In the opposite figure, the distance between the double slit barrier and the observation screen in Young's double-slit experiment equals ............ .




ⓐ 0.4 m ⓑ 0.8 m

ⓒ 1.2 m ⓓ 1.6 m

15 The ratio between the width of the central bright fringe in Young's double-slit experiment when using red light and its width when using violet light with holding the other factors constant is ............ .

ⓐ greater than one ⓑ less than one

ⓒ equal to one ⓓ indeterminable

16 ✻ In Young's double-slit experiment, when using green light of wavelength 550 nm the separation between the centers of two successive interference fringes of the same type is 0.275 mm. When violet light of wavelength 400 nm is used, different fringes were obtained, then the distance between the centers of two successive interference fringes of the same type in the case of violet light equals ............ .

ⓐ 5 mm ⓑ 0.3 mm ⓒ 0.25 mm ⓓ 0.2 mm

17 ✻ In Young's double-slit experiment, if the wavelength of the used light is changed from 400 nm to 600 nm with holding the other factors constant, the distance between the central fringe and the first minima increased by 0.01 mm, then the distance between the central fringe and the second maxima in the first case equals ......... ... .

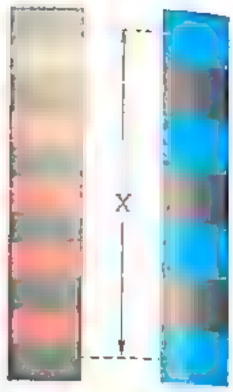
ⓐ 0.01 mm ⓑ 0.02 mm ⓒ 0.04 mm ⓓ 0.08 mm

18 ✻ In Young's double-slit experiment, if the distance between the centers of the fifth bright fringe (maxima) and the central fringe is x, so the distance between the centers of the second dark fringe (minima) and the central fringe is ............ .

ⓐ $\frac{3}{10}$ x ⓑ $\frac{2}{5}$ x

ⓒ $\frac{3}{2}$ x ⓓ $\frac{2}{7}$ x

19 * Young's double-slit experiment has been conducted twice, once using a monochromatic red light and another using a monochromatic blue light while holding the distance between the double slits unaltered, hence the opposite figure represents the interference patterns obtained in both times. If the distances between the double-slit barrier and the screen in both cases are $R_r$ and $R_b$ respectively, then the ratio $\left(\frac{R_r}{R_b}\right)$ is ............ .



First case Second case

ⓐ greater than one ⓑ less than one ⓒ equal to one ⓓ indeterminable

20 * In Young's double-slit experiment, a red light of wavelength 6000 Å fell on a double slit separated by a distance $2 \times 10^{-4}$ m, so an interference pattern appeared on a screen 1 m away from the two slits. If the red light is replaced by a violet light of wavelength 4000 Å with holding the other dimensions of the apparatus unaltered, what is the order of the bright fringe of the violet light whose center will appear at the same position as the second bright fringe of the red light?

ⓐ 1 ⓑ 2 ⓒ 3 ⓓ 4

21 The central fringe in Young's double-slit experiment is formed due to the superposition of the two waves between which the path difference is ............ .

ⓐ 0 ⓑ $\frac{\lambda}{2}$ ⓒ $\lambda$ ⓓ $2\lambda$

22 In Young's double-slit experiment, a monochromatic light of wavelength $\lambda$ is used, so the path difference between the two light waves at the fourth bright fringe equals ............ .

ⓐ $\frac{1}{4}\lambda$ ⓑ $\frac{1}{2}\lambda$ ⓒ $2\lambda$ ⓓ $4\lambda$

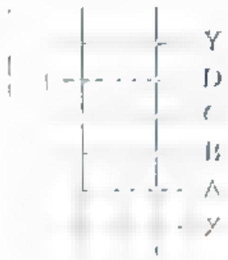
23 In Young's double-slit experiment, a red light of wavelength 6000 Å is used, so if the path difference between the two waves that are initiated from the double-slit to form a definite fringe on the screen is 9000 Å, the formed fringe is ............ .

ⓐ the first dark fringe ⓑ the first bright fringe
ⓒ the second dark fringe ⓓ the second bright fringe

24 In a Young's double-slit experiment, to obtain obvious interference pattern, it is preferable to use a monochromatic source of ............ .

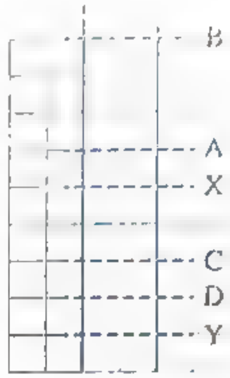
ⓐ green light ⓑ red light ⓒ yellow light ⓓ violet light

25. The opposite figure shows the centers of the interference fringes obtained in a Young's double-slit experiment with a definite drawing scale. If position X represents the center of the central fringe and position Y represents the center of the tenth bright fringe, the center of the fourth bright fringe will be at position




(a) A (b) B
(c) C (d) D

26. The opposite figure shows the centers of the interference fringes obtained in a Young's double-slit experiment with a definite drawing scale. If position X represents the center of the central fringe and position Y represents the center of the second bright fringe, the center of the second dark fringe will be at position ............ .




(a) A (b) B
(c) C (d) D

27. ✻ Suppose that a Young's double-slit experiment is conducted in water instead of air using the same apparatus with the same geometrical arrangement, so the interference fringes ............ .

(a) become fewer (b) become wider (c) become thinner (d) won't appear

28. In a Young's double-slit experiment, the width of a bright fringe was $\Delta y$, if the experiment is repeated with immersing the whole apparatus in a liquid of refractive index n without disturbing its geometrical arrangement, the width of the bright fringe will be ............ .

(a) $\Delta y$ (b) $n\Delta y$ (c) $\frac{\Delta y}{n}$ (d) 0

## Light diffraction

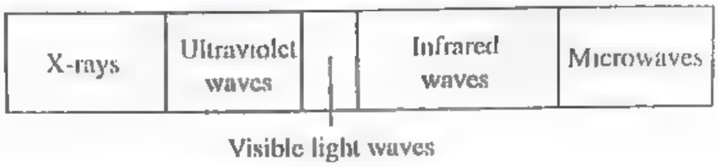
29. When a light wave passes through a slit that is narrow relative to the wavelength of light, the property that changes for the wave is ............ .

(a) the speed (b) the wavelength
(c) the frequency (d) the direction of propagation

30. When light waves fall on different apertures of different sizes, it is expected that the diffraction of light will be most observable if the aperture size is ............ .

(a) 1 m (b) $10^{-2}$ m (c) $10^{-3}$ m (d) $10^{-5}$ m

31 The following diagram represents a given range of the electromagnetic spectrum:

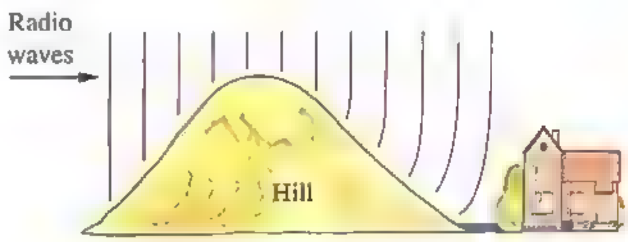



So, which of the following electromagnetic waves gives a more apparent diffraction when it passes through a narrow slit?

ⓐ Infrared waves
ⓑ Microwaves
ⓒ Ultraviolet waves
ⓓ X-rays

---

32 The opposite figure represents a house below the level of the hill top receiving radio waves, so the reason which lets these waves reach the house is the phenomenon of ............ .




ⓐ diffraction
ⓑ interference
ⓒ refraction
ⓓ reflection

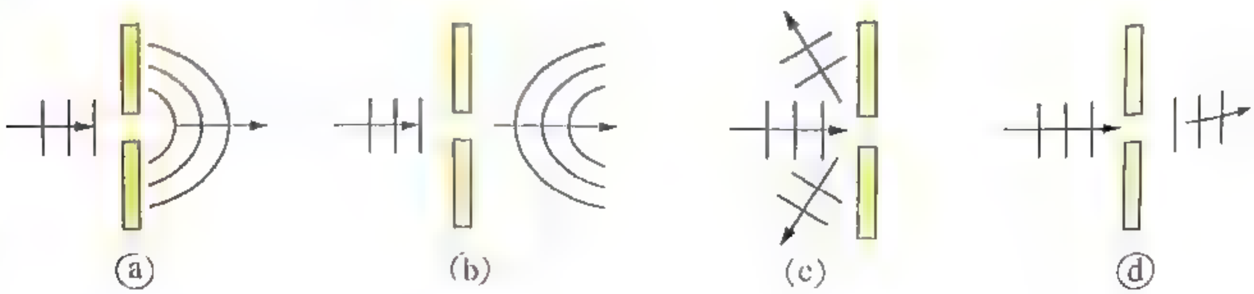
---

33 It is difficult to observe light diffraction in daily life because of ............ .

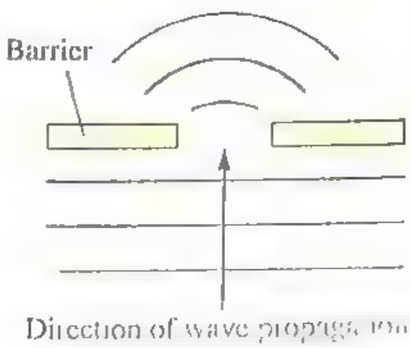
ⓐ the high speed of visible light
ⓑ the small frequencies of visible light
ⓒ the short wavelengths of visible light
ⓓ the high intensity of visible light

---

34 Which of the following diagrams represents correctly the phenomenon of light diffraction when light falls on an aperture?



35 The opposite diagram represents a wavefront of a light wave when passing through an aperture, which of the following changes in the aperture size and the wavelength of light could make the diffraction more obvious?

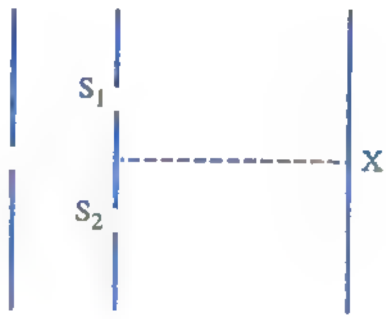



| | Aperture size | Wavelength |
|---|---|---|
| (a) | Decreasing | Increasing |
| (b) | Decreasing | Decreasing |
| (c) | Increasing | Increasing |
| (d) | Increasing | Decreasing |

36 The property of light waves which doesn't get affected in both phenomena of refraction and diffraction is ............ .

(a) the propagation (b) the speed (c) the wavelength (d) the frequency

37 The opposite diagram represents a Young's double-slit experiment, what are the light phenomena that occur at both positions of X and $S_1$?

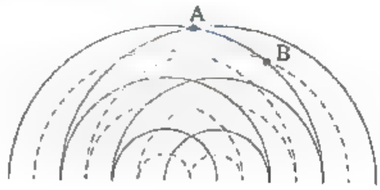



| | Position X | Position $S_1$ |
|---|---|---|
| (a) | Diffraction | Diffraction |
| (b) | Interference | Diffraction |
| (c) | Diffraction | Interference |
| (d) | Interference | Interference |

## Second Essay questions

1 How to get a high noticeable interference pattern in Young's double-slit experiment? **Explain your answer.**

2 What are the types of interference at points A and B?



**3** Young's double-slit experiment is conducted by using red light, what happens to the distance between the formed interference fringes, if:

(a) the distance between the slits is decreased?

(b) blue light is used instead of red?

(c) the frequency of the used light is decreased?

(d) the observation screen is displaced away from the slits?

**4** In Young's double-slit experiment:

(a) **What** did Thomas Young confirm by this experiment?

(b) **Why** did Thomas Young use a monochromatic light?

(c) **How** did Thomas Young get two coherent light sources from one source?

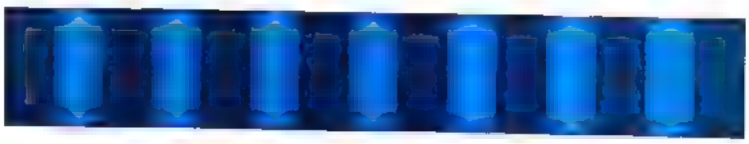
**5** **Explain the following statements:**

(1) The central fringe in Young's double-slit experiment is always bright.

(2) Light diffraction has not been observed when a monochromatic light waves fell on a circular aperture.

(3) There is no big difference between the phenomena of interference and diffraction of light.

**6** A double-slit is lighted by a blue light, so bright and dark fringes are observed as shown in the following figure **what** is the wave phenomenon which makes these fringes appear?

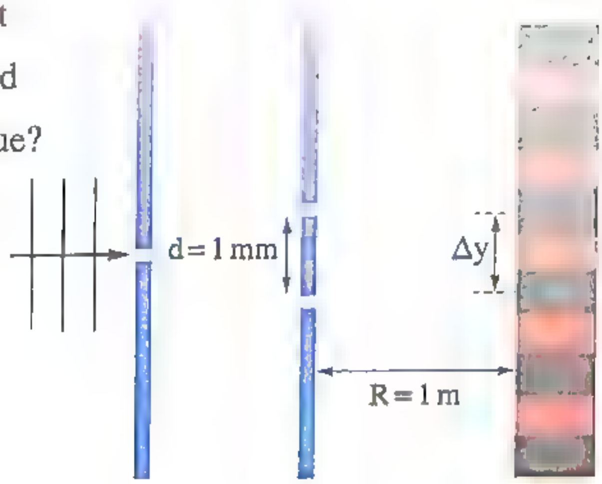


**7** **Write (changes), (constant), (is formed) or (is not formed) in front of each of the following properties of light:**

| | Direction | Frequency | Wavelength | Speed | Dark fringes | Propagation medium |
|---|---|---|---|---|---|---|
| Reflection | | | | | | |
| Refraction | | | | | | |
| Interference | | | | | | |
| Diffraction | | | | | | |

**First : Choose two correct answers in each of the following :**

1. The opposite figure represents Young's double-slit experiment, so which of the following choices lead to decreasing the distance $\Delta y$ to half its initial value?




ⓐ Increasing distance R to 2 m.

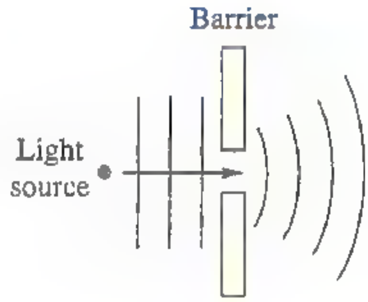
ⓑ Decreasing distance R to 0.5 m.

ⓒ Increasing distance d to 4 mm.

ⓓ Decreasing distance d to 0.5 mm.

ⓔ Increasing distance d to 2 mm.

2. The opposite figure represents the phenomenon of diffraction for a light of wavelength $\lambda$ and frequency $\upsilon$ through an aperture of size d, so to increase the resolution of diffraction, we should use ............. .




ⓐ a light of frequency less than $\upsilon$

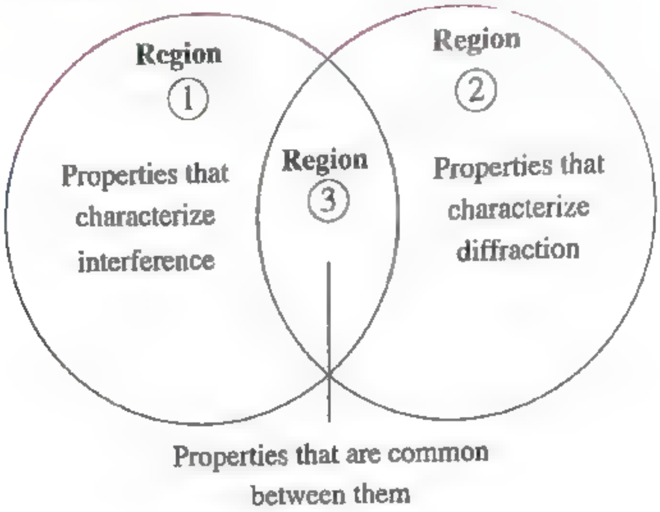
ⓑ a light of frequency higher than $\upsilon$

ⓒ a light of wavelength less than $\lambda$

ⓓ an aperture of size less than d

ⓔ an aperture of size greater than d

**Second:** Put in front of each of the following sente[illegible] of the region that represents it:




(1) To occur, it needs a barrier with two or more slits (Region ............)

(2) It can occur through a narrow single slit (Region ............)

(3) It produces bright and dark fringes (Region ............)

(4) It doesn't lead to changing the frequency or the wavelength of light (Region ............)

(5) In which the distances between the bright fringes are almost equal (Region ............)

(6) In which the central bright fringe is known as Airy's disk (Region ............)


Chapter 2

Lesson Three

# Total Internal Reflection

⊙ Light refraction can be used to explain the occurrence of two phenomena which are :

- **The total internal reflection.**
- **The deviation of light in a triangular prism.**

- In this lesson, we will study the total internal reflection of light in some detail.

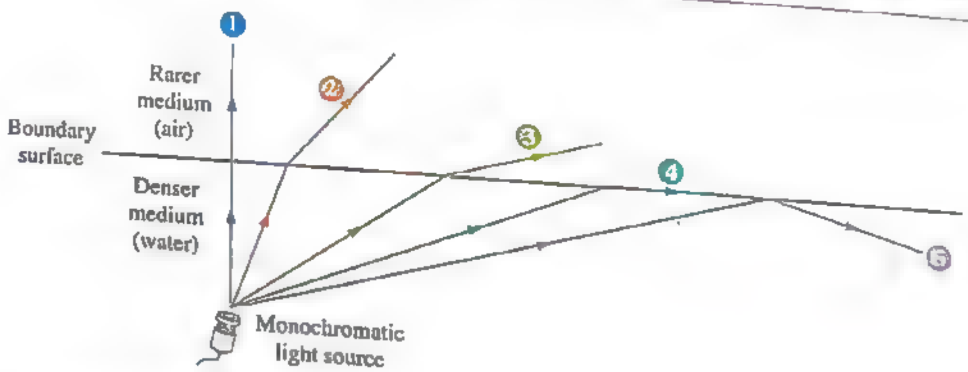
## Total internal reflection

⊙ **Occurrence:**

- When a ray of a monochromatic light falls from an optically denser medium (such as water) on the boundary surface with an optically less dense (rarer) medium (such as air), there will be some possibilities :

| | | |
|---|---|---|
| 1 | If the angle of incidence equals zero (the light ray falls perpendicular on the boundary surface ($\phi = 0$)) | The light ray passes into the optically rarer medium (air) without any refraction ($\theta = 0$) |
| 2 | If the angle of incidence is increased slightly to be greater than zero (the light ray falls at an angle on the boundary surface ($\phi > 0$)) | The light ray passes into the optically rarer medium (air) refracted away from the normal on the boundary surface where : $n_1 \sin \phi = n_2 \sin \theta$ |
| 3 | By increasing the angle of incidence of light gradually | The angle of refraction ($\theta$) in the optically rarer medium (air) increases gradually as: $n_1 \sin \phi = n_2 \sin \theta$ |

| | |
|---|---|
| 4 When the angle of incidence reaches a definite value that is known as the critical angle ($\phi_c$) | The light ray gets refracted tangent to the boundary surface *i.e.*, the angle of refraction of the light ray ($\theta$) equals 90°, so: $n_1 \sin \phi_c = n_2$ |
| 5 When the angle of incidence becomes greater than the critical angle ($\phi > \phi_c$) | The light ray gets reflected back in the optically denser medium (water) so that the angle of incidence = The angle of reflection |




**From the previous, we can define each of the critical angle between two media and the total internal reflection as follows:**

**The critical angle between two media ($\phi_c$):**
It is the angle of incidence of the light ray in the denser medium which leads to a refraction angle of 90° in the rarer medium.

**The total internal reflection:**
It is the reflection of light ray in the denser medium when it is incident at an angle that is greater than the critical angle between the two media.

## Deducing the relation between the critical angle and the refractive index of a medium

- When a light ray passes from an optically denser medium ($n_1$) to an optically rarer medium ($n_2$), Snell's law is applied :

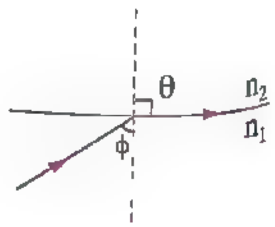
$n_1 \sin \phi = n_2 \sin \theta$

If the light ray falls with an angle of incidence that equals the critical angle ($\phi_c$) between the two media, it gets refracted tangent to the boundary surface:

$\because \phi = \phi_c \quad , \quad \theta = 90°$

$\therefore n_1 \sin \phi_c = n_2 \sin 90°$

$\therefore n_1 \sin \phi_c = n_2$



**If the rarer medium is**

| Air ($n_2 = n_{air} = 1$) | Not air |
|---|---|
| So, | |
| $n_1 = n$ , $n \sin \phi_c = 1$ | $n_1 \sin \phi_c = n_2$ |
| $\sin \phi_c = \frac{1}{n} = \frac{v}{c} = \frac{\lambda_1}{\lambda_2}$ | $\sin \phi_c = \frac{n_2}{n_1} = \frac{v_1}{v_2} = \frac{\lambda_1}{\lambda_2} = {}_1n_2 = \frac{\sin (\phi_c)_1}{\sin (\phi_c)_2}$ |

**Where**

- (n) is the absolute refractive index of the denser medium (n > 1).
- ($\phi_c$) is the critical angle of the medium with air.

- $n_1 > n_2$
- $\phi_c$ is the critical angle between the two media.
- $(\phi_c)_1$ is the critical angle of the first medium with air.
- $(\phi_c)_2$ is the critical angle of the second medium with air.

## Note :

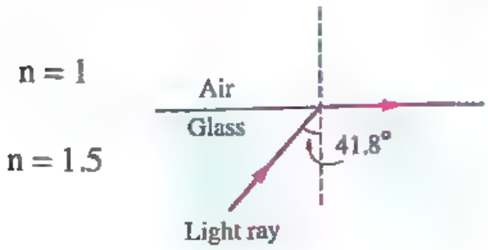
- Knowing that $\sin \phi_c$ is always between 0 and 1 ($0 < \sin \phi_c < 1$), so when calculating the critical angle between two media, the value of the quantity in the numerator must be always less than the value of the quantity in the denominator.

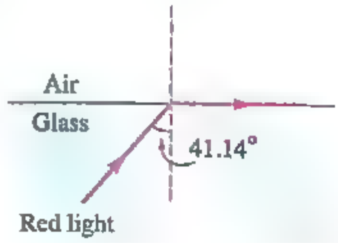
**The factors on which the critical angle between two media depends :**

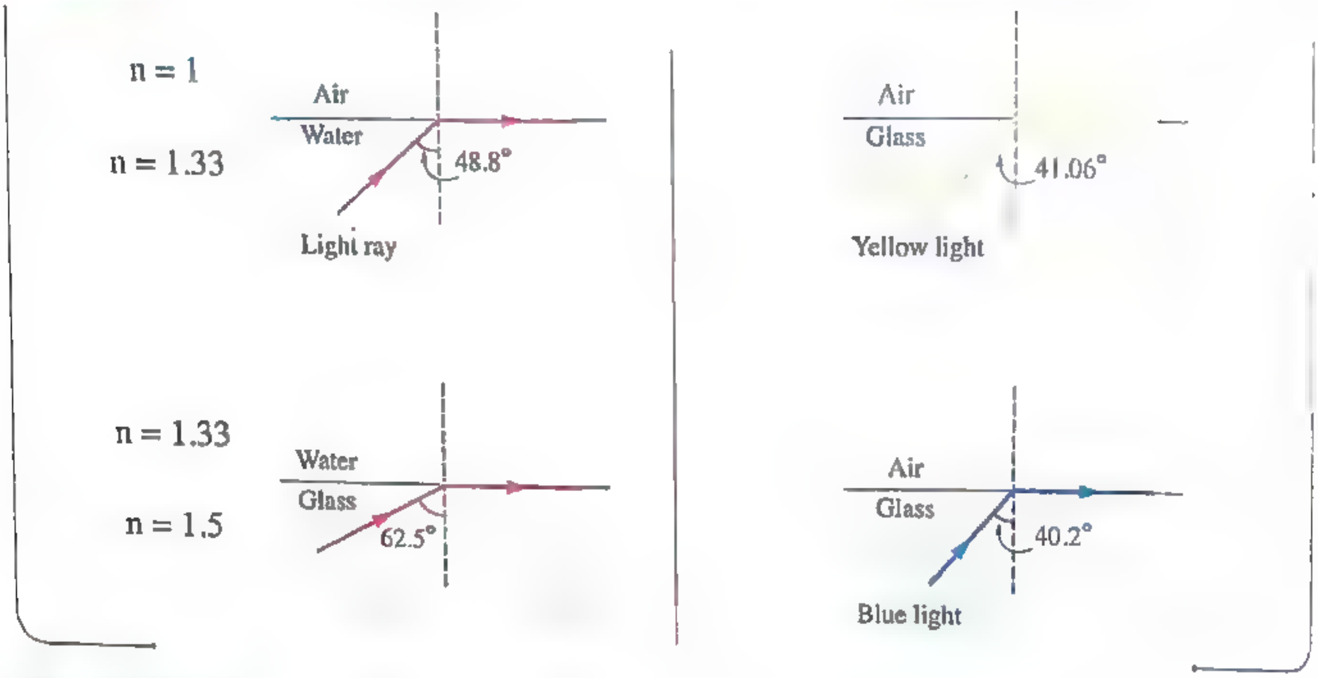
① **The types of material of the two media**

② **The wavelength of the incident light ray**

**Illustration**






**Example 1**

***If the absolute refractive indices of glass and water for a given monochromatic light ray are 1.6 and 1.33 respectively, calculate:***

*(a)* The critical angle for each of them with air.

*(b)* The critical angle for the incident light ray that travels from glass to water.

## Solution

$n_g = 1.6$ | $n_w = 1.33$ | $(\phi_c)_g = ?$ | $(\phi_c)_w = ?$ | $\phi_c = ?$

*(a)* The critical angle between glass and air: $\sin(\phi_c)_g = \frac{1}{n_g} = \frac{1}{1.6}$

$(\phi_c)_g = 38.68°$

The critical angle between water and air: $\sin(\phi_c)_w = \frac{1}{n_w} = \frac{1}{1.33}$

$(\phi_c)_w = 48.75°$

*(b)* $n_g \sin\phi_c = n_w \sin 90$

$\sin\phi_c = \frac{n_w}{n_g} = \frac{1.33}{1.6}$

$\phi_c = 56.23°$

**What if** the used light in this example is replaced by another monochromatic light of shorter wavelength, **what happens to** the critical angles for each of glass and water with air?

## Example 2

*The speeds of propagation of a light wave through two different media (x and y) are $2 \times 10^8$ m/s and $2.75 \times 10^8$ m/s respectively.*
*Calculate the critical angle between the two media*

### Solution

$v_x = 2 \times 10^8$ m/s   $v_y = 2.75 \times 10^8$ m/s   $\phi_c = ?$

$$\sin \phi_c = \frac{n_y}{n_x} = \frac{v_x}{v_y} = \frac{2 \times 10^8}{2.75 \times 10^8}$$

$\phi_c = 46.66°$

**Clue**

*Light travels with the lowest speed through the medium of the highest refractive index.*

**What if** you are asked to calculate the ratio between the critical angles of light for each of the two media with air $\frac{(\phi_c)_x}{(\phi_c)_y}$, what will be your answer?

## Example 3

*A piece of diamond was placed at the bottom of a wide basin filled with water for a height of 1 m, calculate the smallest diameter of a cork disk that while floating on the water surface will be enough to block the reflected light by the diamond from emerging out of the water surface. (Giving that : The absolute refractive index of the water = 1.33)*

### Solution

$h = 1$ m   $n_w = 1.33$   $2r = ?$

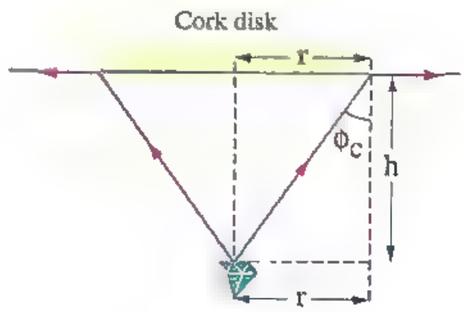
**Clue**

*The smallest disk that can block the reflected light from the diamond has to be put on the water surface in such away that its center is directly above the diamond piece and the angle of incidence of the light rays which reach the edge of the disk is equal to the critical angle.*

$\because \sin \phi_c = \frac{1}{n_w} = \frac{1}{1.33}$ ,   $\therefore \phi_c = 48.75°$

$\because \tan 48.75 = \frac{r}{h} = \frac{r}{1}$ ,   $\therefore r = 1.14$ m

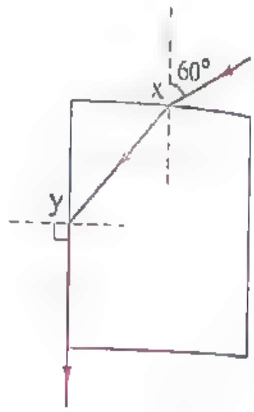
$\therefore$ **The diameter of the disk = $2r = 2.28$ m**



**What if** the height of water in the basin gets increased, what happens to the required diameter for the cork disk that has to float on the surface of water to block out the reflected light from the piece of diamond?

## Example 4

*The opposite figure shows a light ray falling on a transparent slab at point x and emerging tangent to the other face at point y. Calculate the refractive index of the transparent slab.*
*(Giving that : $\sin(90-\theta) = \cos\theta$)*



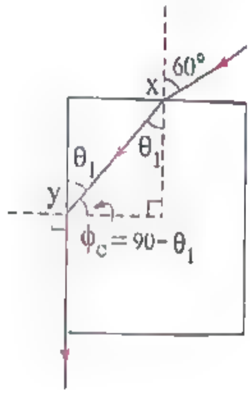

### Solution

$\phi_1 = 60°$ | $\theta_2 = 90°$ | $n = ?$

At point (x) :

$\because n = \frac{\sin\phi}{\sin\theta}$

$\therefore n = \frac{\sin 60}{\sin\theta_1}$ ①




From the figure, we find:

$\phi_c = 90 - \theta_1$

$\therefore n = \frac{1}{\sin\phi_c} = \frac{1}{\sin(90-\theta_1)} = \frac{1}{\cos\theta_1}$ ②

From ① and ②:

$\frac{\sin 60}{\sin\theta_1} = \frac{1}{\cos\theta_1}$

$\frac{\sin\theta_1}{\cos\theta_1} = \tan\theta_1 = \sin 60$

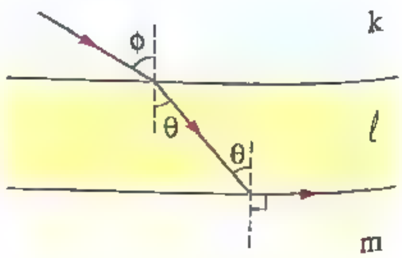
$\therefore \theta_1 = 40.89°$

By substituting in equation ②:

$n = \frac{\sin 60}{\sin 40.89} = 1.32$

## Example 5

*The opposite figure shows the path of a light ray through three media k, $\ell$ and m that have refractive indices $n_k$, $n_\ell$ and $n_m$ respectively, so ……………*




ⓐ $n_\ell > n_k > n_m$
ⓑ $n_k > n_\ell > n_m$
ⓒ $n_m > n_k > n_\ell$
ⓓ $n_\ell > n_m > n_k$

## Solution

∵ The incident light ray on the boundary surface between the two media k and $\ell$ gets refracted towards the normal.

∴ $n_\ell > n_k$

∵ The incident light ray on the boundary surface between the two media $\ell$ and m gets refracted tangent to the surface.

∴ $n_\ell > n_m$

- Applying Snell's law at the boundary surface between the two media k and $\ell$ :

$n_k \sin \phi = n_\ell \sin \theta$ (1)

- Applying Snell's law at the boundary surface between the two media $\ell$ and m :

$n_\ell \sin \theta = n_m \sin 90 = n_m$ (2)

From the two equations (1) and (2) :

∴ $n_k \sin \phi = n_m$  ∵ $\sin \phi < 1$  ∴ $n_k > n_m$

∴ The correct choice is (a) .

**What if** the light ray passes directly from medium k to medium m and falls with the same angle of incidence ($\phi$), what happens to the path of the light ray in medium m?

## 1 Test yourself

**1** A light ray fell from glass on the boundary surface with water, so its wavelength changed from 5000 Å to 5625 Å, **calculate** the critical angle from glass to water.

..............................................................................................................

..............................................................................................................

..............................................................................................................

**2** If the critical angle of glass with air is 41.81° and the critical angle of oil with air is 43.23°, **calculate** the critical angle of glass with oil.

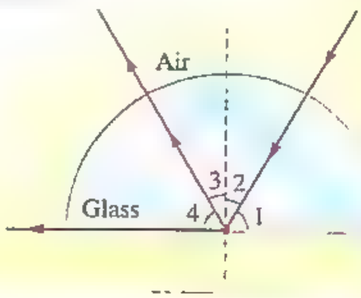
..............................................................................................................

..............................................................................................................

..............................................................................................................

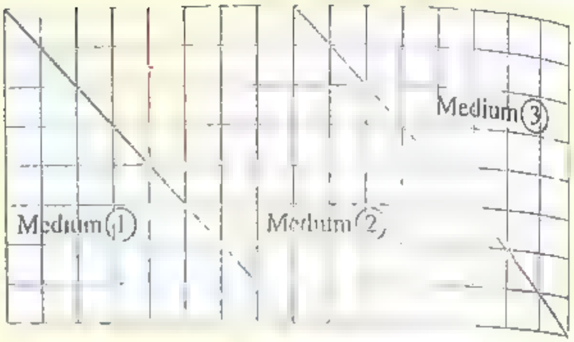
**3** **Choose the correct answer :**

(1) In the opposite figure, which angle is representing the critical angle?




(a) Angle (1)  (b) Angle (2)
(c) Angle (3)  (d) Angle (4)

(2) The opposite figure shows three transparent media ①, ② and ③, so if a light ray passes as shown in the figure, what will be the correct order of light speeds through these three media?

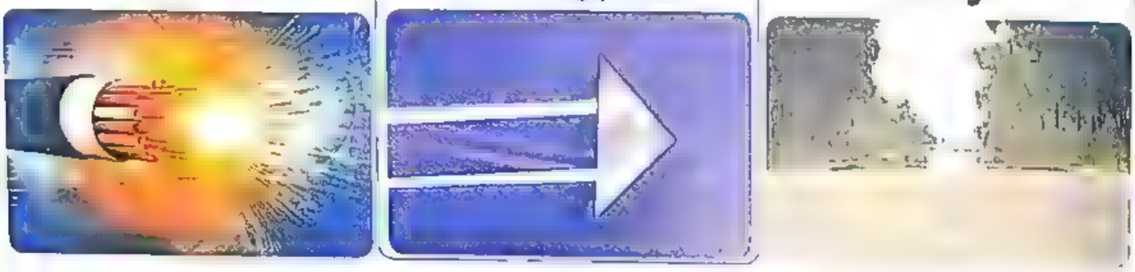



ⓐ $v_1 > v_2 > v_3$ ⓑ $v_1 > v_3 > v_2$

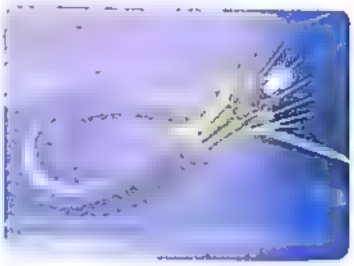
ⓒ $v_2 > v_3 > v_1$ ⓓ $v_3 > v_2 > v_1$

## Applications of the total internal reflection of light

1 Optical fibers (fiberoptics) 2 Reflecting prism 3 Mirage



### 1 Optical fibers (fiberoptics)

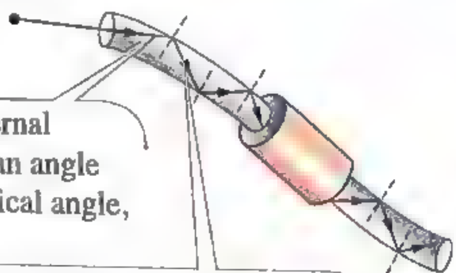


⊙ **Structure:**

It is a thread-like tube of a transparent elastic material, which has a relatively high refractive index.

⊙ **Idea of working:** Total internal reflection.

⊙ **Explaining the idea of working:**




① When a light ray falls on the internal surface of the optical fiber with an angle of incidence greater than the critical angle,

② The light ray undergoes multiple successive total internal reflections till it emerges from the other end without any noticeable loss in the light intensity despite of bending this fiber.

⊙ Uses:

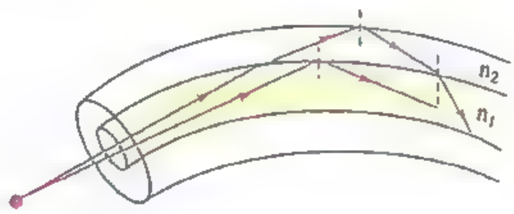
1. Transferring light to parts which are hard to reach.
2. Transmitting light in non-straight paths without much losses in the light intensity.
3. They are widely used nowadays in medical examination devices such as medical endoscopes, which are used in:
   - Diagnosis.
   - Operative surgery using laser beam.
4. Communication as light can carry signals of data in optical fiber cables.

## Note :

- **Optical fiber that are made of two layers are preferred to the optical fibers that are made of only one layer;**

Because the refractive index of the material of the external layer ($n_2$) is less than that of the internal layer ($n_1$).

Hence, the external layer reflects any part of light that may escape from the internal layer by total internal reflection so that light is kept travelling inside the fiber.

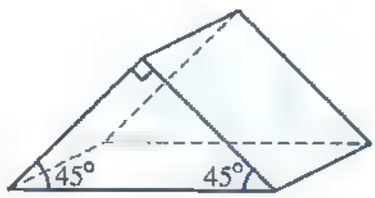



Accordingly, the intensity of the transmitted light by the optical fiber can be kept constant, which increases the efficiency of light transferring.

## 2 Reflecting prism

⊙ **Structure:**

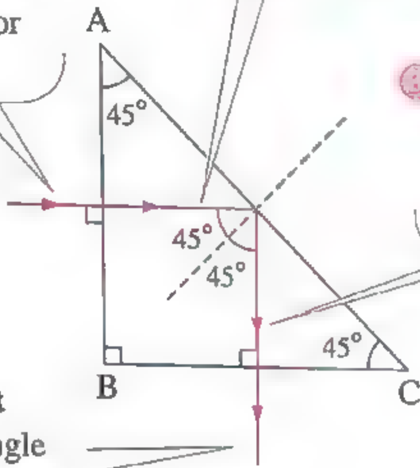
A triangular glass prism whose angles are 45°, 45° and 90° that is made of glass of refractive index 1.5 *i.e.* its critical angle with air is 41.8° (≈ 42°).




⊙ **Idea of working:** Total internal reflection.

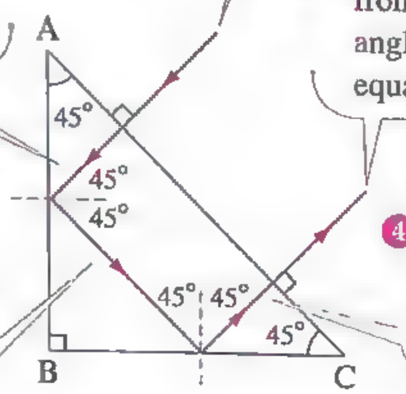
⊙ **Usage:**

## (1) Changing the path of the light ray by 90°



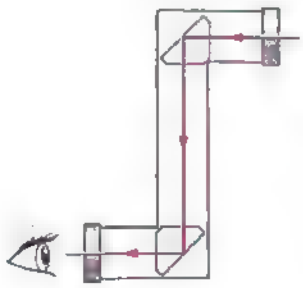
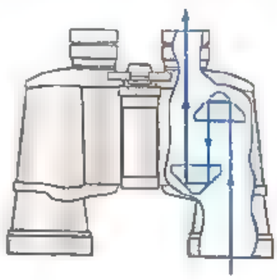

1. When a light ray is incident normally on one of the adjacent faces to the right angle of the prism (AB for instance).
2. The ray passes straight and falls on the face (AC) opposite the right angle by an angle of incidence 45°, *i.e.*, with an angle that is greater than the critical angle of glass.
3. The light ray gets reflected totally by an angle 45°, then the reflected ray falls normally on the other adjacent face to the right angle (BC).
4. The ray emerges straight from face BC with an angle of refraction that equals zero.

## (2) Changing the path of the light ray by 180°




1. When a light ray is incident normally on the face (AC) opposite the right angle.
2. The ray passes straight to fall on one of the adjacent faces to the right angle (AB for instance) by an angle of 45°, *i.e.*, with an angle greater than the critical angle for glass.
3. The light ray gets reflected totally by an angle of 45° to fall on the other adjacent face (BC) to the right angle with an angle of 45°.
4. The ray gets reflected totally for the second time and falls normally on the face (AC) opposite the right angle.
5. The ray emerges straight from face AC with an angle of refraction that equals zero.

☆ **From the previous, we can compare the two uses of reflecting prism as follows :**

| | To change the path of the light ray by 90° | To change the path of the light ray by 180° |
|---|---|---|
| **The prism's face on which the light ray falls** | One of the right angled faces (face AB) | The face opposite the right angle (hypotenuse AC) |
| **The angle of incidence (ϕ)** | Zero | Zero |
| **The deviation angle of light** | 90° | 180° |
| **The angle of ray emergence** | Zero | Zero |
| **The prism's face from which the light ray emerges** | The other face of the right-angled faces (face BC) | The same face of light entrance (hypotenuse AC) |
| **The number of total internal reflections inside the prism** | One time | Two times |
| **An optical instrument that uses the prism** |  ***Periscope*** |  ***Binocular*** |

## Notes :

1. Reflecting prisms are preferred to metallic reflecting surfaces or mirrors in some optical instruments for the following reasons:
   ① Because they reflect light totally while there is no other reflecting surface of efficiency 100 %.
   ② In addition, a metallic surface eventually loses its luster, hence its reflection efficiency decreases, this does not happen in a prism.

2. The faces of a reflecting prism are coated with non-reflective layer of a material like cryolite (aluminum fluoride and magnesium fluoride) whose refractive index is less than that of glass.
Thus, the critical angle between glass and cryolite becomes small to avoid any reflection losses on the faces of the prism and increase its efficiency.

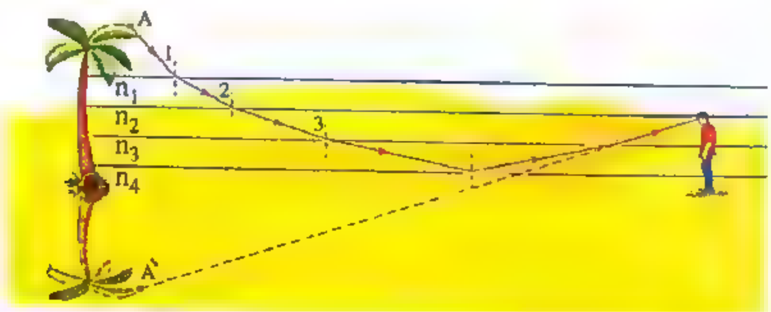
## 3 Mirage

◉ **Mirage is a common phenomenon at the noon times during the very hot days, for example:**

1. Car drivers see the roads as if they are covered with water.
2. Hills and palms appear as inverted images such as the image formed due to reflection on water surface.
So, the observer thinks that there is water and this phenomenon is known as **mirage**.

◉ **Explanation of mirage phenomenon:**

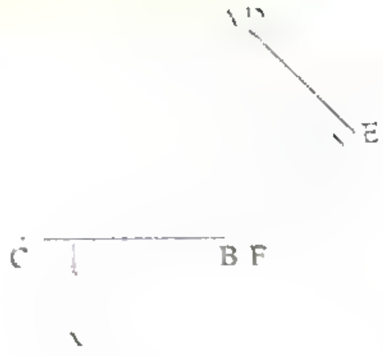
- In extremely hot days, the temperature of air layers adjacent to the Earth's surface increases so that their density decreases more than the upper layers. Accordingly the refractive index of the upper layers ($n_1$) become larger than that of the lower layers ($n_2$).
- When a light ray that is coming from an object passes from the upper air layers (optically denser layers) to the lower air layers (optically rarer layers);
① It refracts away from the normal according to Snell's law, where : $n_1 \sin \phi = n_2 \sin \theta$
② The deviation of the light ray increases as it passes through air layers taking a curved path.
③ When the angle of incidence of the light ray in one layer becomes greater than the critical angle with the following layer, the light ray gets reflected totally till reaching the observer's eye, hence the eye sees the image (the tree) inverted on the extension of the light rays that reach the eye as if it is reflected on water, so the observer thinks that there is water on the ground.



## Test yourself

**Choose the**

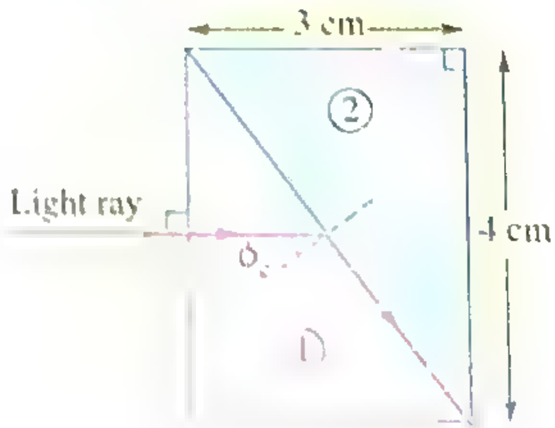
**1** ✱ The opposite figure represents two reflecting triangular prisms. When a light ray (x) is incident perpendicular on face BC, the ray emerges from face .........




ⓐ AC  ⓑ DE

ⓒ EF  ⓓ BC

**2** In the opposite figure, a light ray passes through one of two similar triangular prisms ① and ② of different materials, so what is the relative refractive index between their materials ($_1n_2$)?




ⓐ 0.6  ⓑ 0.8

ⓒ 0.9  ⓓ 1.67

Chapter 2

Questions on Lesson Three

# Total Internal Reflection

To watch videos of how to solve questions use the App

The questions signed by ✳ are answered in detail.

Higher Order Thinking Skills

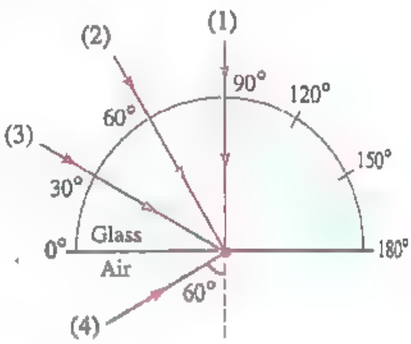
Interactive test

## First Multiple choice questions

1. The total internal reflection for an incident light ray from an optically denser medium to an optically rarer medium occurs when the angle of incidence is ........ .

(a) equal to 90°
(b) greater than the critical angle
(c) equal to the critical angle
(d) less than the critical angle

2. The opposite figure represents four incident light rays on a semi-circular glass prism whose refractive index is 1.5, which of these rays undergoes total internal reflection?



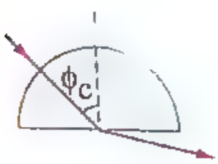

(a) Ray (1)
(b) Ray (2)
(c) Ray (3)
(d) Ray (4)

3. The opposite table shows the absolute refractive indices of three materials x, y and z, hence total internal reflection could happen when light travels from ............. .

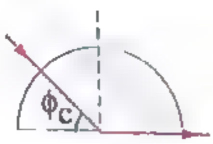
| Material | Refractive index |
|---|---|
| x | 1 |
| y | 1.33 |
| z | 1.5 |

(a) material x to material y
(b) material x to material z
(c) material y to material z
(d) material z to material y

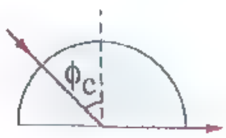
4. The figure that represents the correct path for an incident light ray on a semi-circular glass prism in which the angle $\phi_c$ equals the critical angle is ............ .



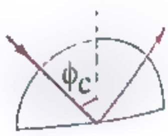

(a)




(b)

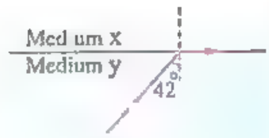


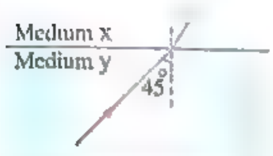

(c)



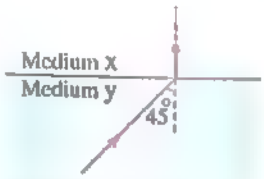

(d)

**5** In the opposite figure, if the angle of incidence becomes 45°, which of the following figures represents the correct path of the ray ?

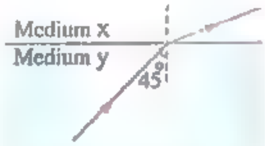


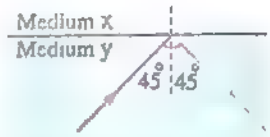

(a)




(b)




(c)




(d)

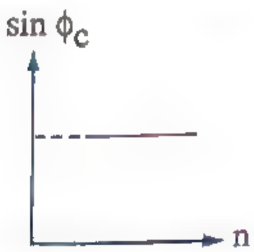
**6** The largest angle of refraction for a light beam passing from water of refractive index $\frac{4}{3}$ to air is ............ .

(a) 41.82° (b) 48.59° (c) 90° (d) 180°

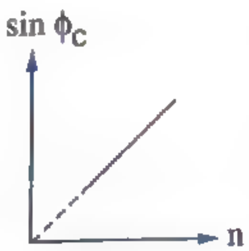
**7** The critical angle between two media depends on ............ .

(a) the absolute refractive index of the optically denser medium only
(b) the absolute refractive index of the optically rarer medium only
(c) the absolute refractive indices of the two media
(d) the angle of incidence of the light ray on the boundary surface between the two media

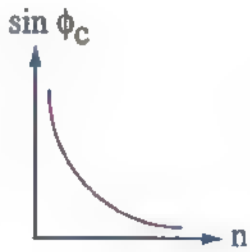
**8** Which of the following figures represents the graph of sine of the critical angle ($\sin \phi_c$) for multiple transparent materials surrounded by air versus the absolute refractive index (n) for each of the materials?



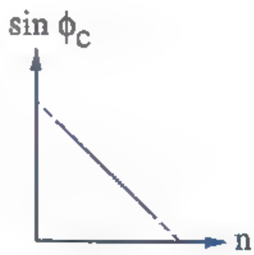

(a)




(b)




(c)




(d)

**9** ✱ A light ray falls from air on a liquid surface. If the angle of incidence is 30° and the angle of refraction is 22°, then the critical angle for the ray when it passes from the liquid to air is ............ .

(a) 22° (b) 30° (c) 41.4° (d) 48.5°

**10** If the critical angle of a medium with air is 42°, the refractive index of this medium equals ............ .

(a) $\sqrt{2}$ (b) 1.73 (c) 1.64 (d) 1.49

**11** If the refractive index of glass is $\sqrt{2}$, the biggest angle of incidence that lets a light ray emerge from glass to air and doesn't get reflected totally equals ............ .

(a) 30° (b) 45° (c) 60° (d) 75°

**12** If the critical angle for a light ray from a glass slab of refractive index 1.52 to another medium of refractive index n is 45°, then the value of n equals ............ .

(a) 1 (b) 1.07 (c) 1.33 (d) 1.52

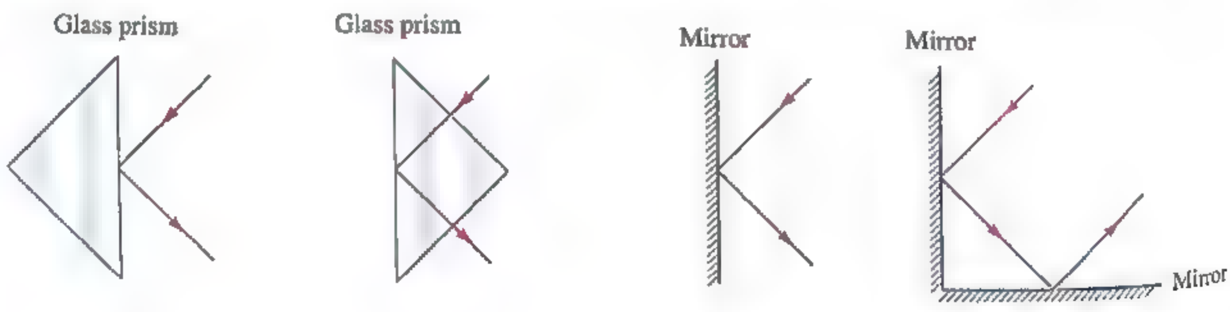
**13** A container of glass of refractive index 1.65 contains a liquid of refractive index 1.32, so the critical angle between them is ............ .

(a) 37.31° inside the glass (b) 37.31° inside the liquid
(c) 53.13° inside the glass (d) 53.13° inside the liquid

**14** ✻ Three transparent materials x, y and z have critical angles with air $(\phi_c)_x$, $(\phi_c)_y$ and $(\phi_c)_z$ respectively, giving that a total internal reflection could happen when light travels from material x to material y and also when it travels from material y to material z, which of the following mathematical expressions relates the critical angles of each of these materials surrounded by air?

(a) $(\phi_c)_x > (\phi_c)_y > (\phi_c)_z$ (b) $(\phi_c)_y < (\phi_c)_x < (\phi_c)_z$
(c) $(\phi_c)_x = (\phi_c)_y = (\phi_c)_z$ (d) $(\phi_c)_x < (\phi_c)_y < (\phi_c)_z$

**15** Which of the following diagrams represents a total internal reflection of a light ray?




(a) (b) (c) (d)

**16** ✻ If the speed of light in air is $3 \times 10^8$ m/s and in another medium is $1.33 \times 10^8$ m/s, then the critical angle of that medium with air equals ............ .

(a) 26.32° (b) 32.26° (c) 63.68° (d) 68.63°

**17** If the critical angle for a light ray travelling from medium a to medium b is $\phi_c$ and the speed of light in medium a is v, then the speed of light in medium b is ......

(a) $v \sin \phi_c$ (b) $v \cos \phi_c$ (c) $\frac{v}{\cos \phi_c}$ (d) $\frac{v}{\sin \phi_c}$

**18** ✻ If the critical angle from glass to air is 42° and the critical angle from water to air is 48°, then:

**(i)** The relative refractive index from glass to water equals ........... .

(a) 0.8 (b) 0.9 (c) 1.11 (d) 1.8

**(ii)** The critical angle from glass to water equals ............ .

(a) 25.84° (b) 45° (c) 64.16° (d) 90°

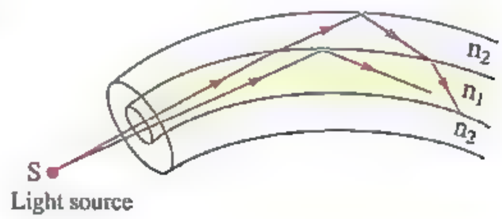
**19** ✻ The wavelengths of a light ray in two media x and y are 5500 Å and 4000 Å respectively, then the critical angle between the two media equals .......... .. .

(a) 11.43° (b) 43.11° (c) 46.66° (d) 89.46°

**20** ✻ A light ray is incident at an angle of 54° from air on the surface of a transparent medium, so a part of the ray is reflected and the other part is refracted. If the reflected and the refracted rays are perpendicular to each other, the critical angle of the transparent medium with air is ............ .

(a) 28.4° (b) 35.4° (c) 42.4° (d) 46.4°

**21** The opposite figure shows how the incident light rays from source S pass through an optical fiber made of two layers, hence the ratio between the absolute refractive indices of the internal and the external layers $\left(\frac{n_1}{n_2}\right)$ of the fiber ............ .




(a) is greater than one (b) is less than one

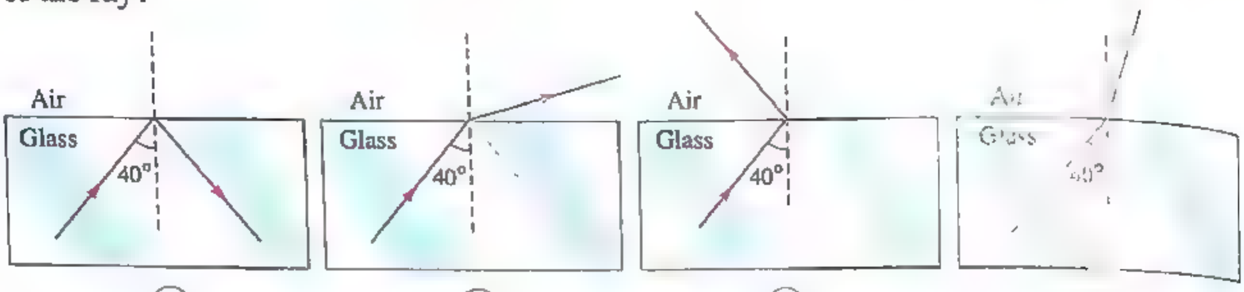
(c) might be greater or less than one (d) is equal to one

**22** A physician used an endoscope to examine a digestive tract tumor for a patient, the working principle of this endoscope is based on the phenomenon of ............ .

(a) light refraction (b) light interference

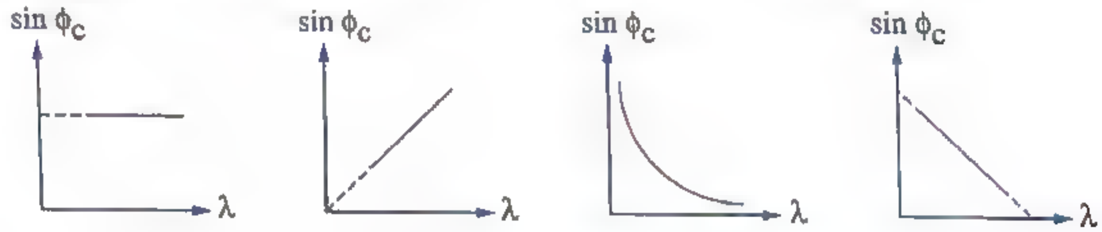
(c) total internal reflection of light (d) light diffraction

23. A light ray is incident with an angle of incidence 40° on the boundary surface between glass of refractive index 1.5 and air, so which of the following figures represents the path of the ray?



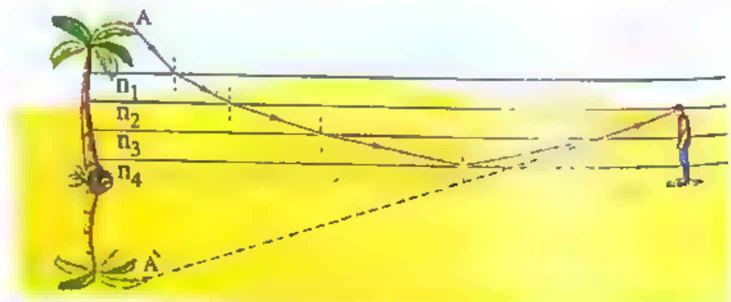

ⓐ ⓑ ⓒ ⓓ

24. Which of the following graphs represents the relation between the sine of the critical angle ($\sin \phi_c$) of a medium surrounded by air and the wavelength ($\lambda$) of the incident light in this medium?




ⓐ ⓑ ⓒ ⓓ

25. The opposite figure shows the occurrence of mirage, hence the correct order of refractive indices of air layers is ............



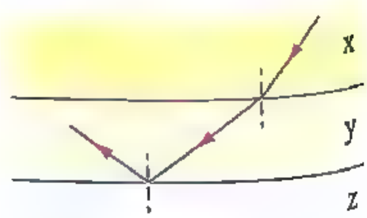

ⓐ $n_3 < n_2 < n_1$

ⓑ $n_1 < n_2 < n_3$

ⓒ $n_2 < n_1 < n_3$

ⓓ $n_3 < n_1 < n_2$

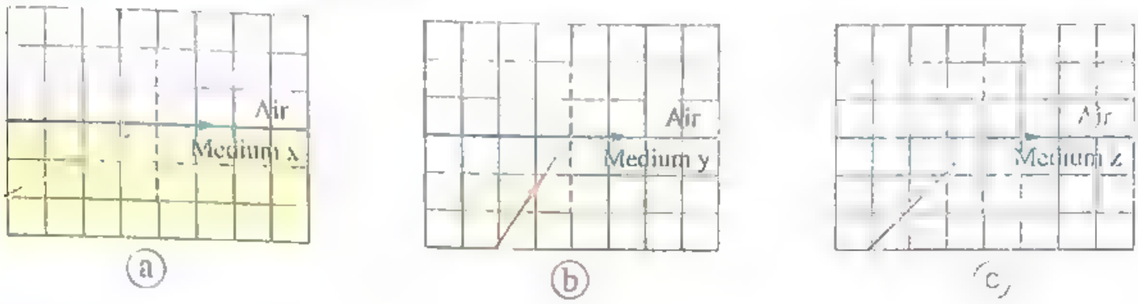
26. ✻ The opposite figure represents a light ray passing from medium x to medium y towards medium z, so the relation among the absolute refractive indices for these media $n_x$, $n_y$ and $n_z$ is ............




ⓐ $n_x < n_y < n_z$ ⓑ $n_z < n_y < n_x$

ⓒ $n_z < n_x < n_y$ ⓓ $n_y < n_x < n_z$

**27** Three transparent materials have absolute refractive indices $n_x$, $n_y$ and $n_z$, a light ray is incident on the interface of each of them with air as represented in the following figures,

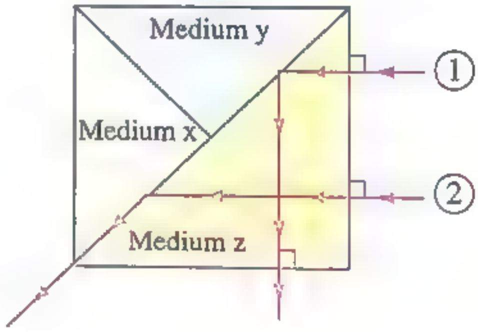



so, the speed of light ............ .

(a) is higher in medium x
(b) is higher in medium y
(c) is higher in medium z
(d) is the same in all of them

---

**28** ✻ The opposite figure shows the paths of two light rays, so what is the correct order for the absolute refractive indices of the three media x, y and z?




(a) $n_z < n_y < n_x$
(b) $n_y < n_x < n_z$
(c) $n_z < n_x < n_y$
(d) $n_x < n_y < n_z$

---

**29** ✻ A lamp is submerged in a liquid of refractive index $\sqrt{2}$ at a depth of 20 cm, then:

(i) The radius of the smallest floating disk on the surface of the liquid which is enough to block the light of the lamp is ............ .

(a) 0.05 cm
(b) 0.7 cm
(c) 20 cm
(d) 40 cm

(ii) If the depth of the lamp is increased under the liquid surface, then the radius of the disk needed to block the light of the lamp should ............ .

(a) increase
(b) decrease
(c) remain constant
(d) no correct answer

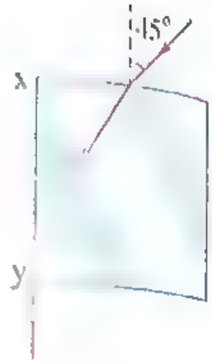
---

**30** ✻ If $n_{glass} > n_{gasoline} > n_{water}$, the critical angle from glass to gasoline is $(\phi_c)_1$ and the critical angle from glass to water is $(\phi_c)_2$, the ratio $\frac{(\phi_c)_1}{(\phi_c)_2}$ is ............ .

(a) less than 1
(b) greater than 1
(c) equal to 1
(d) indeterminable

31 ✱ A light ray is incident on a square glass slab as in the figure, then the refractive index of the glass that makes the ray emerges tangent to the vertical face (xy) of the slab equals ............ .

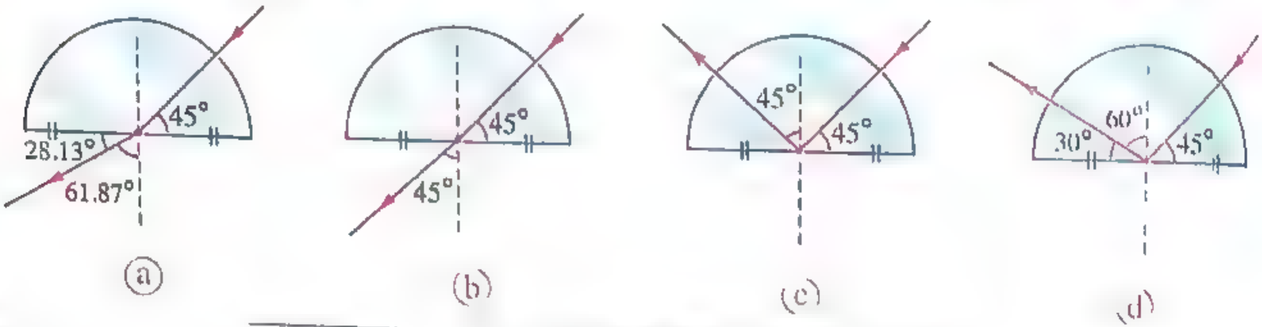
(Where: $\sin(90° - \theta) = \cos\theta$)




(a) 0.816 (b) 1.15

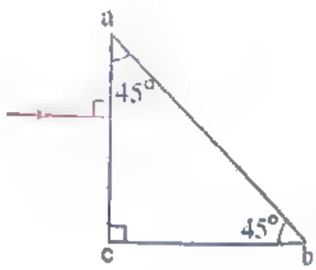
(c) 1.225 (d) 1.375

32 ✱ A light ray is incident on a semi-circular glass prism whose refractive index is 1.5, which of the following diagrams represents the correct path for the incident light ray?




33 In the opposite figure :

(i) If the refractive index of the prism is 1.5, the incident ray on face ab ............ .




(a) emerges with an angle 45°

(b) emerges with an angle 60°

(c) emerges with an angle 90°

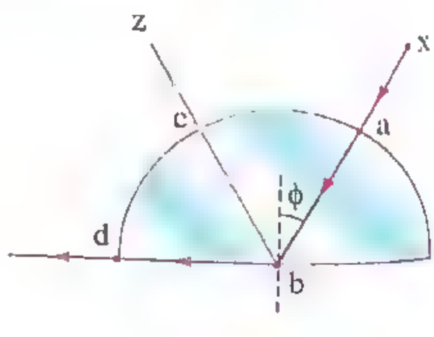
(d) undergoes total internal reflection

(ii) If the refractive index of the prism is $\sqrt{2}$, the incident ray on face ab ............ .

(a) undergoes total internal reflection (b) emerges with an angle 60°

(c) emerges with an angle 82° (d) emerges tangent to that face

34 In the opposite figure, what happens for the light rays when increasing the angle of incidence $\phi$?




(a) Ray xa suffers a total internal reflection at point a.

(b) Ray bc suffers a total internal reflection at point c.

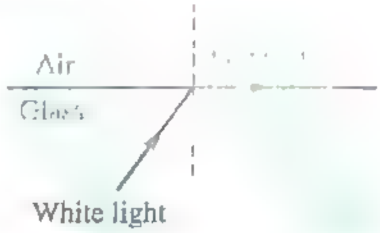
(c) The intensity of ray bz increases.

(d) The intensity of ray bd increases.

35 Which light color has the least value of critical angle in glass surrounded by air?

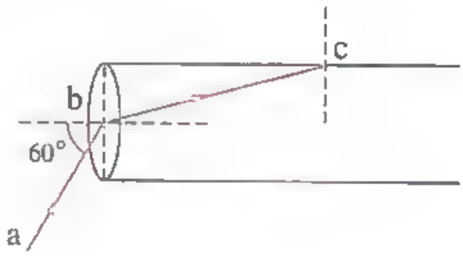
(a) Red (b) Green (c) Yellow (d) Violet

36 A beam of white light is incident on the boundary surface between glass and air as shown in the opposite figure, hence the green light gets refracted tangent to the boundary surface, so the light rays that emerges into air are the rays of colors ............ .



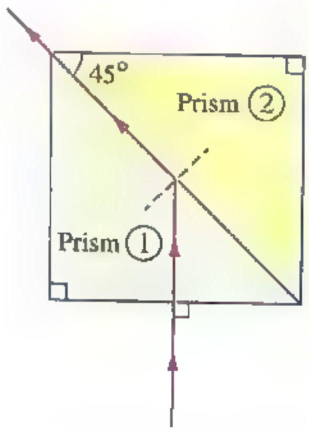

(a) yellow, orange and red
(b) violet, indigo and blue
(c) red and blue
(d) yellow and violet

37 A light ray is incident with an angle of incidence 60° into an optical fiber of material refractive index 1.68, so it gets refracted as in the opposite figure. What happens to the light ray at point c?



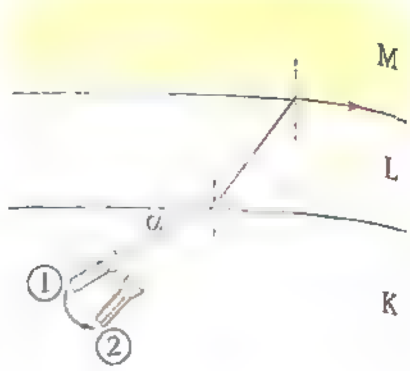

(a) It undergoes a total internal reflection by an angle of 58.97°
(b) It undergoes a total internal reflection by an angle of 49.24°
(c) It gets refracted by an angle of 45.25°
(d) It gets refracted by an angle of 36.52°

38 The opposite figure represents the path of a light ray through two triangular prisms (1) and (2) of different materials that are placed completely adjacent to each other, if the refractive index of the material of prism (2) is 1.55, the refractive index of the material of prism (1) equals ............ .




(a) 2.27
(b) 2.22
(c) 2.19
(d) 2.14

39 Three layers of transparent materials (M, L, K) through which a light ray passes from material K towards material M as shown in the opposite figure, if the light source is moved from position ① to position ② such that the angle α gets increased, the light ray when it falls on the boundary surface between material L and material M will ............ .



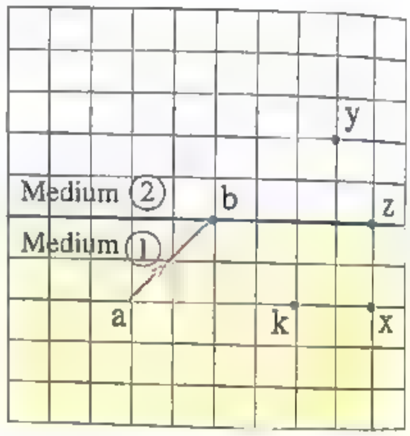

ⓐ be refracted towards the normal

ⓑ be refracted away from the normal

ⓒ be refracted tangent to the boundary surface

ⓓ undergoes total internal reflection

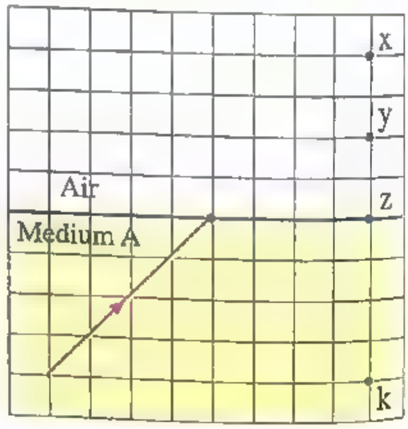
40 A light ray ab is incident from medium ① whose refractive index is n towards medium ② whose refractive index is less than n as represented by the drawing scale shown in the figure, so if the critical angle between these two media is 26°, the light ray will pass from point b to point ............ .




ⓐ x ⓑ y

ⓒ z ⓓ k

41 The opposite figure shows a light ray falling from medium A of refractive index n on the boundary surface with air, hence that light ray can not pass by point ............ .




ⓐ x

ⓑ y

ⓒ z

ⓓ k

42 ✳ A light ray falls from glass on the boundary surface with air at an angle of incidence that equals the critical angle, so it gets refracted tangent to the glass surface. If a layer of water is placed on the glass surface, then the angle of emergence of the ray to air equals .. .......... .

(Given that : the refractive index of glass = 1.5, the refractive index of water = $\frac{4}{3}$)

ⓐ 42° ⓑ 48° ⓒ 62° ⓓ 90°

## Essay questions

**1** **Explain the following statements:**

(1) Despite the falling of a light ray from an optically denser medium to an optically rarer medium, it doesn't undergo total internal reflection

(2) When light is emitted from a source beneath the surface of water, it may not be seen in air.

(3) Optical fibers are used in medical endoscopes.

(4) Prisms are preferred to mirrors as reflectors in some optical instruments.

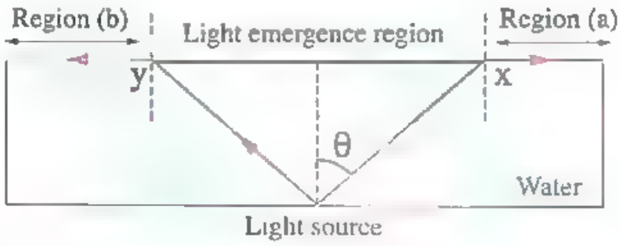
(5) The appearing of mirage in hot deserts.

---

**2** Four light rays are emitted from a light source under the surface of a liquid of refractive index $\sqrt{2}$. If the first ray falls perpendicularly on the surface of the liquid, the second falls at an angle of incidence 30°, the third at 45° and the fourth at 60°, **describe what happens for each ray.**

---

**3** The opposite figure shows a light source at the bottom of a water container.




(a) **Why** doesn't light emerge from regions (a) and (b)?

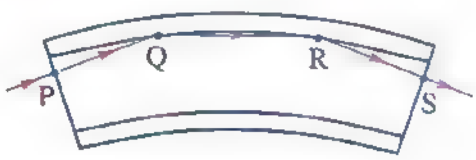
(b) **Calculate** the value of the angle θ.

(Where: The refractive index of water = 1.33)

---

**4** In the opposite figure :

An optical fiber is coated by a thin film whose refractive index is less than that of the fiber's core. If a light beam passes through it as shown in the figure, **explain why:**



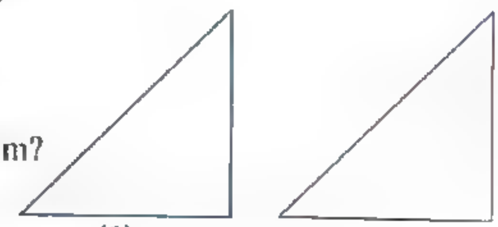

(a) the direction of the beam does not change at each of S and P.

(b) there is total reflection at each of Q and R.

(c) the double layer in the optical fiber is preferred to that of a single layer.

---

**5** The opposite figure shows two reflecting prisms where prism (2) is coated with a transparent thin film of another material.

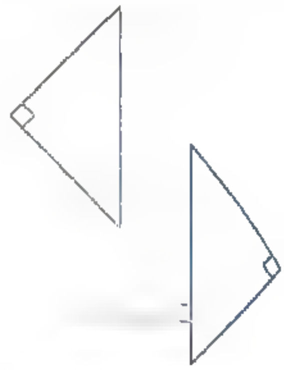


(1) (2)

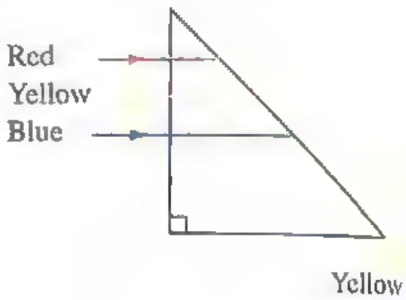
(a) **What** could be the type of the material of the thin film?

(b) **Which** of the two prisms is more efficient? **And why?**

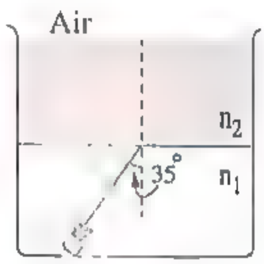
**6** The opposite figure represents two reflecting prisms. If a light ray falls perpendicular on a face of one of them, **trace** the path of the light ray until it emerges from the other prism.



**7** The opposite figure shows a right angle isosceles triangular prism where three different colors of light rays fall on one of the adjacent faces to the right angle. So, if the yellow ray emerges tangent to the opposite face of the right angle, **trace** the path of the other red and blue rays, **with explanation**.




**8** The opposite figure shows a light lamp which is placed at the bottom of a container under two layers of different liquids. The refractive index of the lower layer is 2 while the refractive index of the upper one is 1.5. A light ray falls from the lamp on the boundary between the two liquids at an angle of incidence 35°. **Trace the light ray and show if the ray will emerge to the air or not.**



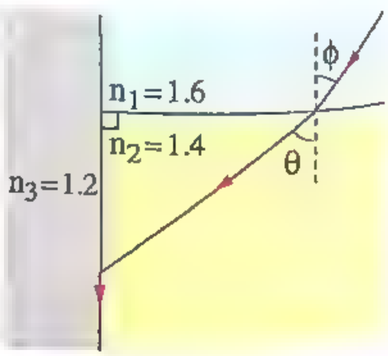

**9** Three light sources were placed away from each other at the bottom of water basin the first source gives yellow light, the second gives red light and the third gives blue light. When the three sources are switched on, three circular light spots of different areas have appeared on the surface of water. **Arrange** the sources ascendingly according to the area of the spot circle and **explain why** each light source has different spot circle area.

**10** The opposite figure shows a light ray that travels through medium 1 then falls on the boundary surface between the two media (1, 2) where it enters medium 2 and falls on the boundary surface between the two media (2, 3) at an angle that equals the critical angle for them:

(a) **Calculate** the value of angle $\phi$.

(b) **Does** the ray pass into medium (3) if the value of the angle $\phi$ increases? **Explain your answer.**

(Note that: $\sin(90° - \theta) = \cos\theta$)

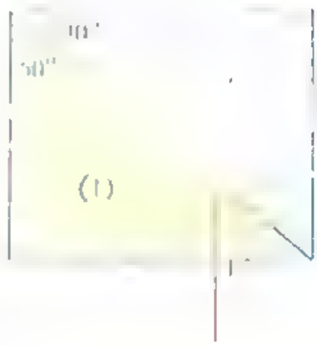


## New Types of questions

Understand   Apply   Higher Order Thinking Skills

**First : Choose two correct answers in each of the following**

**1** Two triangular prisms (1) and (2) of different materials are placed tightly adjacent to each other, so when a light ray passes towards prism (2) whose material absolute refractive index is 1.35, the ray follows the path shown in the opposite figure, so ............




ⓐ the absolute refractive index of the material of prism (1) = 1.76

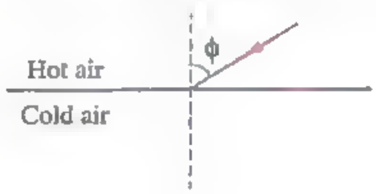
ⓑ the absolute refractive index of the material of prism (1) = 2.1

ⓒ the relative refractive index from material of prism (1) to that of prism (2) = 0.64

ⓓ the relative refractive index from material of prism (1) to that of prism (2) = 0.766

ⓔ the relative refractive index from material of prism (1) to that of prism (2) = 1.6

**2** In the following cases a light ray falls on the boundary surface between two media. If angle $\phi$ is greater than the critical angle between the two media, in which of these cases the light ray suffers a total internal reflection ?

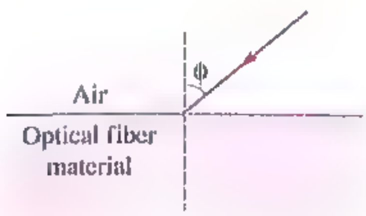



ⓐ


ⓑ


ⓒ


ⓓ




ⓔ

**Second:** Put in front of each of the following sentences the suitable n... the figure that represents it:


**Figure (1)**

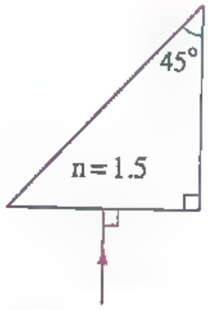



**Figure (2)**

(1) In which, the ray undergoes total internal reflections at two different faces of the prism (Figure .....)

(2) In which, the ray changes its path by 180° (Figure .....)

(3) In which, the ray changes its path by 90° (Figure .....)

(4) In which, the two angles of incidence of the ray inside the prism are 45° and 0° respectively (Figure .....)

(5) In which, the ray represents what happens in the binocular (Figure .....)

Why

if a laser beam is pointed to fall on one of the faces of a triangular prism, the beam deviates from its path?

Chapter 2

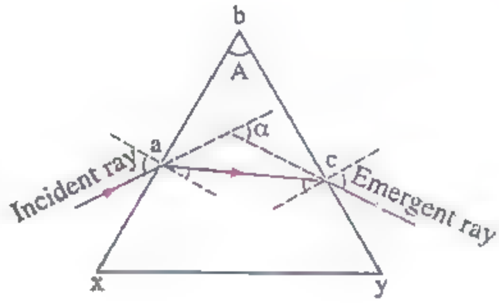
Lesson Four

# Deviation of Light in a Triangular Prism

**Triangular prism :**

It is a piece of a solid transparent material (like glass) with two identical faces in the shape of a triangle connected by three lateral rectangular faces.

- If a light ray falls from air on face xb of the opposite triangular prism;
- It gets refracted inside the prism taking the path ac.
- So, it falls on face yb and if its angle of incidence on face yb is less than the critical angle between the material of the prism and the air, it gets refracted and emerges from the face yb of the prism.

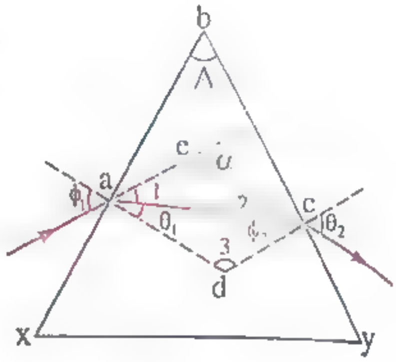



***i.e.*** The light ray is deviated from its path due to passing through the prism by a certain angle called **the angle of deviation (α)**, which can be defined as follows:

**The angle of deviation (α) :**
It is the acute angle between the extensions of the incident light ray and the emergent light ray.

## Deducing the laws of a triangular prism

In the triangular prism shown in the opposite figure:

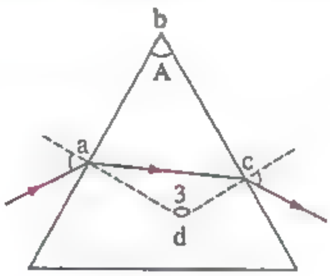



- **A** is the apex angle of the prism (the angle between the two faces of the prism where the light ray enters through one of them and emerges from the other one)
- **$\phi_1$** is the first angle of incidence (where light enters)
- **$\theta_1$** is the first angle of refraction
- **$\phi_2$** is the second angle of incidence (inside the prism)
- **$\theta_2$** is the angle of emergence
- **$\alpha$** is the angle of deviation

**Hence, we can deduce each of:**

### First The apex angle of the prism (A)

**1**




$\because \overline{ad} \perp \overline{ab}$ , $\overline{dc} \perp \overline{cb}$

*i.e.* $\angle$ bad = 90° , $\angle$ bcd = 90°

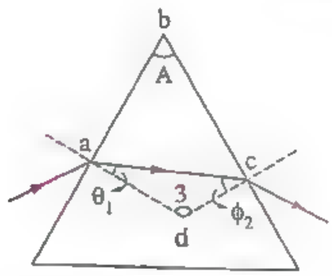
$\therefore \angle$ bad + $\angle$ bcd = 180°

$\therefore$ Shape abcd is cyclic quadrilateral.

$\therefore$ The sum of each two opposite angles = 180°

$\therefore A + \hat{3} = 180°$

**2**




In the triangle acd :

$\because$ The sum of angles = 180°

$\therefore \theta_1 + \phi_2 + \hat{3} = 180°$

From **1** and **2**

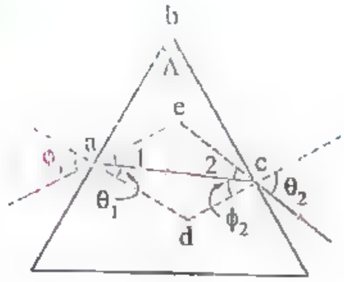
**3**

$\therefore A + \hat{3} = \theta_1 + \phi_2 + \hat{3}$

$\therefore \boxed{A = \theta_1 + \phi_2}$

## Second: The angle of deviation ($\alpha$)

1

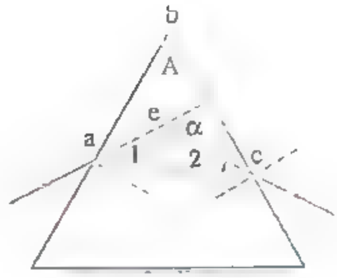



$\because \phi_1 = \hat{1} + \theta_1 \quad , \quad \theta_2 = \hat{2} + \phi_2$

(since they are vertical opposite angles)

$\therefore \hat{1} = \phi_1 - \theta_1 \quad , \quad \hat{2} = \theta_2 - \phi_2$

2




$\because$ The angle of deviation is an exterior angle of the triangle aec.

$\therefore \alpha = \hat{1} + \hat{2}$

From (1) and (2)

3

$$\therefore \alpha = \phi_1 - \theta_1 + \theta_2 - \phi_2$$

$$= \phi_1 + \theta_2 - (\theta_1 + \phi_2)$$

$$\because A = \theta_1 + \phi_2$$

$$\therefore \boxed{\alpha = \phi_1 + \theta_2 - A}$$

## Third: The refractive index of the material of the prism (n)

- When a light ray passes from a medium to a prism such that if the medium is:

| Air | Then | Other medium, not air |
|---|---|---|
| $n_{prism} = \dfrac{\sin \phi_{1\,(air)}}{\sin \theta_{1\,(prism)}} = \dfrac{\sin \theta_{2\,(air)}}{\sin \phi_{2\,(prism)}}$ | | ${}_{medium}n_{prism} = \dfrac{n_{prism}}{n_{medium}} = \dfrac{\sin \phi_{1\,(medium)}}{\sin \theta_{1\,(prism)}} = \dfrac{\sin \theta_{2\,(medium)}}{\sin \phi_{2\,(prism)}}$ |

☆ **If the triangular prism is surrounded by air, then the factors that affect each of:**

**The angle of refraction ($\theta_1$)** are:

1. The refractive index of the prism for the used light (n).
2. The first angle of incidence ($\phi_1$).

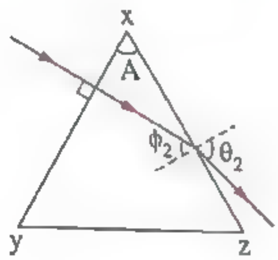
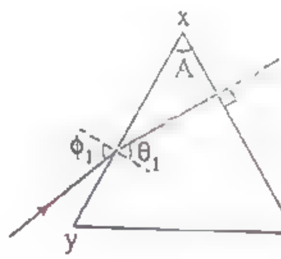
**The second angle of incidence ($\phi_2$)**

**The angle of emergence ($\theta_2$)**

**The angle of deviation ($\alpha$)** are:

1. The refractive index of the prism for the used light (n).
2. The first angle of incidence ($\phi_1$).
3. The apex angle (A).

## Special cases for the triangular prism

| ❶ **When the light ray falls normal on the face of the prism** | ❷ **When the light ray emerges normal from the face of the prism** |
|---|---|
| **The ray** | |
| enters through face xy without any refraction | emerges from face xz without any refraction |
|  |  |
| **Such that** | |
| $\phi_1 = \theta_1 = 0°$ (the minimum value for the first angle of incidence) | $\phi_2 = \theta_2 = 0°$ (the minimum value for the angle of emergence) |
| **So that** | |
| $\phi_2 = A$ (the maximum value for the second angle of incidence) | $\theta_1 = A$ (the maximum value for the second angle of incidence) |
| **At the emergence of the ray from face xz** | |
| $\alpha = \theta_2 - A$ | $\alpha = \phi_1 - A$ |

**3 When the second angle of incidence ($\phi_2$) equals the critical angle of the prism:**

In this case $\phi_1$ is the minimum angle of incidence on the face of the prism that makes the ray em

tangent to t

$\because \phi_2 = \phi_c$

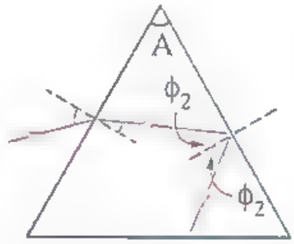
$\therefore n = \frac{1}{\sin \phi_c}$ , $A = \theta_1 + \phi_c$

**4 When the second angle of incidence (inside the prism) is greater than the critical angle of the prism:**

The ray encounters total internal reflection where:

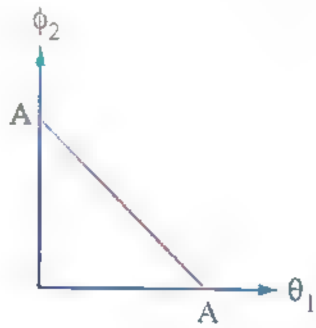
The angle of reflection = The second angle of incidence

And the ray falls on the third face of the prism.




## Notes:

(1) The graph of the second angle of incidence ($\phi_2$) versus the angle of refraction ($\theta_1$) can be represented as shown in the opposite figure, where: $\phi_2 = A - \theta_1$




(2) When a light ray is incident with an angle ($\phi_1$) on one of the faces of a triangular prism such that the second angle of incidence ($\phi_2$) is less than the critical angle ($\phi_c$), the ray emerges from the opposite face with an angle of emergence ($\theta_2$) and when increasing the first angle of incidence ($\phi_1$):

| | | | |
|---|---|---|---|
| The first angle of refraction ($\theta_1$) | increases | since | $n = \frac{\sin \phi_1}{\sin \theta_1}$ |
| The second angle of incidence ($\phi_2$) | decreases | since | $A = \phi_2 + \theta_1$ |
| The angle of emergence ($\theta_2$) | decreases | since | $n = \frac{\sin \theta_2}{\sin \phi_2}$ |

## Method of solving the problems of triangular p

**1** When a light ray falls on one of the lateral faces of a triangular prism, we use Snell's law:

$$n_1 \sin \phi_1 = n_2 \sin \theta_1$$

Where: $n_1$ is the refractive index of the surrounding medium, $n_2$ is the refractive index of the prism.

**2** When the light ray passes inside the prism and falls on the opposite face, we use the relation:

$$A = \theta_1 + \phi_2$$

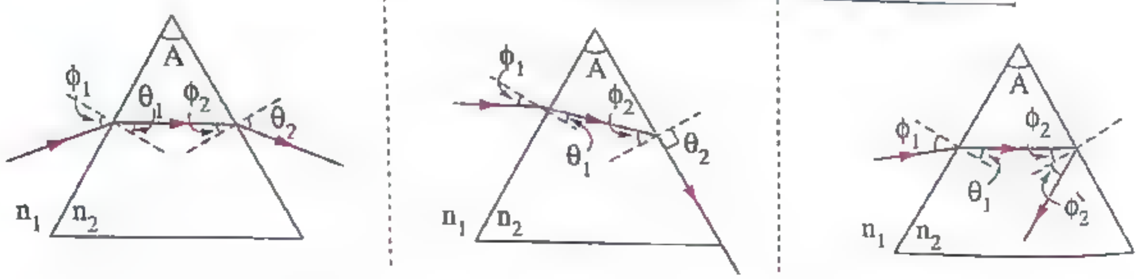
**3** From the geometry of the figure, we calculate the angle of incidence of the light ray on the internal surface of the prism and compare it with the critical angle of the prism with its surrounding medium to determine the path of the light ray at that surface, so if the second angle of incidence (inside the prism):

| is less than | equals | is greater than |
|---|---|---|
| **the critical angle between the material of the prism and the surrounding medium ($\phi_2 < \phi_c$)** | **the critical angle between the material of the prism and the surrounding medium ($\phi_2 = \phi_c$)** | **the critical angle between the material of the prism and the surrounding medium ($\phi_2 > \phi_c$)** |

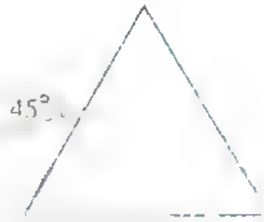
**Hence, the light ray**

| | | |
|---|---|---|
| gets refracted away from the normal line on the face of the prism, so we apply Snell's law: $n_2 \sin \phi_2 = n_1 \sin \theta_2$ | gets refracted tangent to the face of the prism so that: $\theta_2 = 90°$ | undergoes total internal reflection inside the prism so that: The angle of reflection $= \phi_2$ |

**And this can be represented by the following diagram**



## Example 1




*The opposite figure represents a light ray that is incident at an angle of 45° on one of the faces of an equilateral triangular prism whose refractive index equals 1.5, so:*

*(i)* The angle at which the ray emerges from the prism equals .........

a 28.13° b 31.87° c 42.12° d 52.37°

*(ii)* The angle of deviation for the light ray equals .........

(a) 37.37° b 41.43° c 52.63° d [illegible]

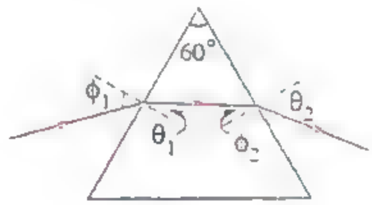
## Solution

$\phi_1 = 45^\circ$ | $A = 60^\circ$ | $n = 1.5$ | $\theta_2 = ?$ | $\alpha = ?$

**Clue**

*(i)*

*To find the angle of emergence* $(\theta_2)$, *we must calculate* $\theta_1$ then $\phi_2$.




Applying Snell's law:

$\sin\phi_1 = n\sin\theta_1$

$\sin\theta_1 = \dfrac{\sin 45}{1.5}$

$\theta_1 = 28.13^\circ$

$A = \theta_1 + \phi_2$

$\phi_2 = A - \theta_1 = 60 - 28.13 = 31.87^\circ$

$\because \sin\phi_c = \dfrac{1}{n} = \dfrac{1}{1.5}$

$\therefore \phi_c = 41.81^\circ$

By comparing the second angle of incidence $(\phi_2)$ with the critical angle of the prism's material, we find:

$\phi_2 < \phi_c$

$\therefore$ The ray passes from the face of the prism so that Snell's law is applied:

$\sin\theta_2 = n\sin\phi_2 = 1.5\sin 31.87^\circ$

$\therefore \theta_2 = 52.37^\circ$

$\therefore$ **The correct choice is (d).**

*(ii)* $\alpha = \phi_1 + \theta_2 - A$

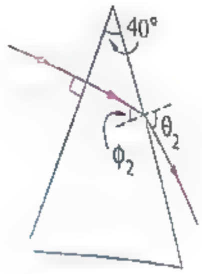
$= 45 + 52.37 - 60 = 37.37^\circ$

$\therefore$ **The correct choice is (a).**

**What if** we need to make the light ray undergo a total internal reflection inside the prism, **what** change should be done to the angle of incidence to do that?

## Example 2

*The opposite figure shows a light ray which is incident normally on one of the faces of a triangular prism of an apex angle 40°, if $\theta_2 = 1.5\ \phi_2$, the refractive index of the prism equals ........*




ⓐ 1.25 ⓑ 1.35

ⓒ 1.51 ⓓ 1.72

### Solution

$A = 40°$ | $\theta_2 = 1.5\ \phi_2$ | $\theta_1 = \phi_1 = 0°$ | $n = ?$

$\because A = \theta_1 + \phi_2$ , $\theta_1 = 0°$

$\therefore \phi_2 = A = 40°$ $\therefore \theta_2 = 1.5 \times 40 = 60°$

• Applying Snell's law : $n \sin \phi_2 = \sin \theta_2$

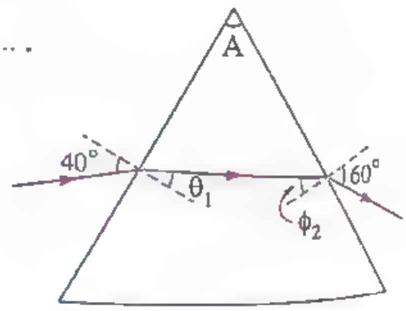
$$n = \frac{\sin \theta_2}{\sin \phi_2} = \frac{\sin 60}{\sin 40} = 1.35$$

$\therefore$ **The correct choice is ⓑ.**

**What if** the angle of incidence of the light ray is changed to make the ray emerges normally, **what** will be the new angle of incidence on the prism ($\phi_1$)?

## Example 3

*The opposite figure represents the path of a light ray through a triangular prism, hence the angle of refraction $\theta_1$ is ..............*




ⓐ greater than the second angle of incidence ($\phi_2$)

ⓑ less than the second angle of incidence ($\phi_2$)

ⓒ equal to the second angle of incidence ($\phi_2$)

ⓓ equal to the apex angle of the prism (A)

### Solution

$$\because n = \frac{\sin \phi_1}{\sin \theta_1} = \frac{\sin \theta_2}{\sin \phi_2}$$

$$\therefore \frac{\sin 40}{\sin \theta_1} = \frac{\sin 60}{\sin \phi_2}$$

$\because \sin 60 > \sin 40$

$\therefore \sin\theta_1 < \sin\phi_2$

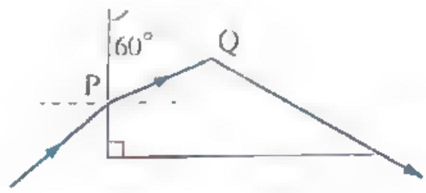
$\therefore \theta_1 < \phi_2$

$\therefore$ **The correct choice is (b).**

**What if** the angle of incidence ($\phi_1$) of the light ray on the prism gets increased, what will happen to the angle of emergence of the light ray?

## Example

*In the opposite figure, a blue light ray falls on the face of a prism at point P so that the angle of refraction equals 23° then it falls on the opposite face at point Q and emerges tangent to that face, hence:*




*(i)* The critical angle of the prism's material for the blue light equals .............. .

ⓐ 23° ⓑ 37°

ⓒ 42° ⓓ 60°

*(ii)* The refractive index of the prism's material for the blue light equals ............. .

ⓐ 1.15 ⓑ 1.41

ⓒ 1.66 ⓓ 1.72

## Solution

$\theta_1 = 23°$ | $A = 60°$ | $\theta_2 = 90°$ | $\phi_c = ?$ | $n = ?$

*(i)* $A = \theta_1 + \phi_2$ , $\therefore 60 = 23 + \phi_2$ , $\therefore \phi_2 = 37°$

$\because$ The ray has emerged tangent.

$\therefore \phi_c = \phi_2 = 37°$

$\therefore$ **The correct choice is ⓑ.**

*(ii)* $n = \frac{1}{\sin\phi_c} = \frac{1}{\sin 37} = 1.66$

$\therefore$ **The correct choice is ⓒ.**

**What if** the blue light ray is replaced by a red light ray that falls at the same angle on the prism, will the light ray undergo total internal reflection at the face of the prism opposite the right angle?

## Example 5

*In the opposite figure, if the refractive index of the prism's material is 1.5:*

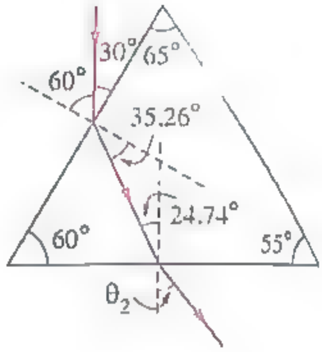

(a) ***Trace*** the light ray inside the prism.

(b) ***Find*** the angle of emergence from the prism.

(c) ***Find*** the angle of deviation.

### Solution

$n = 1.5$ | $\theta_2 = ?$ | $\alpha = ?$




(a) Applying Snell's law: $\sin \phi_1 = n \sin \theta_1$

$$\sin \theta_1 = \frac{\sin \phi_1}{n} = \frac{\sin 60}{1.5}$$

$\theta_1 = 35.26°$ , $A = \theta_1 + \phi_2$

$60 = 35.26 + \phi_2$ , $\phi_2 = 24.74°$

(b) $\sin \phi_c = \frac{1}{n} = \frac{1}{1.5}$ , $\phi_c = 41.81°$

By comparing the second angle of incidence ($\phi_2$) with the critical angle for the prism ($\phi_c = 41.81°$), we find: $\phi_2 < \phi_c$

- Applying Snell's law :

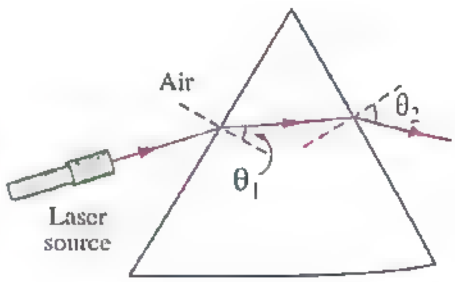
$\sin \theta_2 = n \sin \phi_2 = 1.5 \times \sin 24.74$ $\theta_2 = 38.88°$

(c) $\alpha = (\phi_1 + \theta_2) - A$

$= 60 + 38.88 - 60 = 38.88°$

## Example 6

*A triangular prism of material's refractive index 1.5 is placed at the bottom inside an empty sink where a laser ray is incident on it and emerges as shown in the opposite figure. If water of refractive index 1.33 is poured into the sink till it has covered the prism, what happens to the angle of refraction ($\theta_1$) and that of emergence ($\theta_2$)?*




(a) Both angles decrease.

(b) $\theta_1$ increases and $\theta_2$ decreases.

(c) $\theta_1$ decreases and $\theta_2$ increases.

(d) Both angles increase.

## Solution

When the prism is surrounded by air:

$\sin \phi_1 = n_{prism} \sin \theta_1$ (1)

When the prism is surrounded by water:

$n_{water} \sin \phi_1 = n_{prism} \sin \grave{\theta}_1$ (2)

Dividing equation (1) by (2):

$$\frac{1}{n_{water}} = \frac{\sin \theta_1}{\sin \grave{\theta}_1}$$

$\therefore \sin \grave{\theta}_1 = n_{water} \sin \theta_1$

$\because n_{water} > 1$

$\therefore \sin \grave{\theta}_1 > \sin \theta_1$

$\therefore \theta_1$ increases when the prism is surrounded by water.

$\because A = \theta_1 + \phi_2$

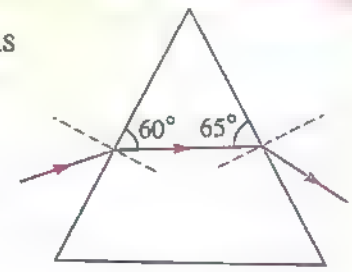
$\therefore$ When $\theta_1$ increases, $\phi_2$ decreases, so $\theta_2$ decreases.

$\therefore$ **The correct choice is (b).**

**What if** in the first case (before pouring water into the sink), the light source has been changed by another of higher frequency, **what will be** the effect of this change on the angle of emergence of the light ray from the prism?

## Test yourself

**1** ✱ In the opposite figure, if the refractive index of the prism is 1.5, **calculate** the deviation angle of the light ray.




..............................................................................................

..............................................................................................

..............................................................................................

**2** **Choose the correct answer :**

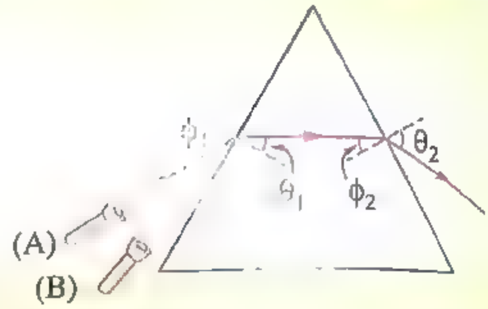
(1) A light ray is incident with an angle of incidence $\phi_1$ on one of the lateral faces of a triangular prism whose material refractive index is n, hence it deviates by an angle $\alpha$, so if the prism is immersed in a liquid of refractive index 0.8 n and a light ray gets incident on it with the same angle $\phi_1$, the deviation angle of the light ray .............. .

(a) decreases (b) increases (c) vanishes (d) doesn't change

(2) In the opposite figure, if the light source is moved from position (A) to position (B), the angle of emergence ($\theta_2$) .............. .

(a) decreases (b) increases

(c) vanishes (d) doesn't change

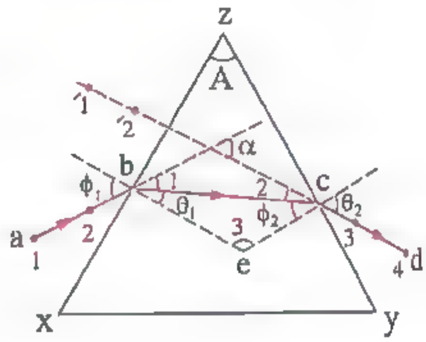



## Practical Experiment

**Tracing the path of a light ray through a triangular prism and confirming the laws of the prism.**

### Tools:

- An equilateral glass triangular prism (of apex angle 60°).
- A protractor. - A ruler. - Pins.




### Steps:

1. Place the glass prism on a drawing paper sheet and mark its position with a fine pencil line.
2. Draw a line ab inclined to one of the faces of the prism to represent the incident ray.
3. Place two pins (1, 2) on the line ab.
4. Look at the other side of the prism to see the image of the two pins, one behind the other.
5. Place two other pins (3) and (4) exactly in front of pins (1) and (2) such that the four pins appear to be in one straight line.
6. Draw a straight line cd between the two pins (3) and (4) to represent the emergent ray.
7. Remove the prism and the pins and join b and c to locate the path of the ray (abcd) from air to glass to air again.
8. Extend cd to meet the extension of ab. The acute angle between them is the angle of deviation ($\alpha$).
9. Measure: $\phi_1, \theta_1, \phi_2, \theta_2$ and $\alpha$ using the protractor.
10. Record the results in a table as the following:

| 1st angle of incidence ($\phi_1$) | Angle of refraction ($\theta_1$) | 2nd angle of incidence ($\phi_2$) | Angle of emergence ($\theta_2$) | Angle of deviation ($\alpha$) | Apex angle (A) |
|---|---|---|---|---|---|
| | | | | | |

11. Compare the results with the calculated values from the relations:

$A = \theta_1 + \phi_2 \quad , \quad \alpha = (\phi_1 + \theta_2) - A$

Chapter 2

Questions on Lesson Four

# Deviation of Light in a Triangular Prism

To watch videos of how to solve questions use the App

MaalakApp

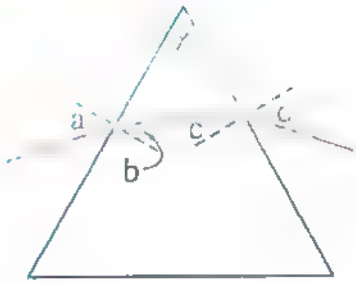
Interactive test

The questions signed by ✳ are answered in detail.

Apply    Higher Order Thinking Skills

## First Multiple choice questions

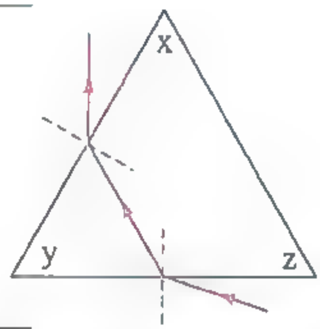
1 The opposite figure represents the path of a light ray through a triangular prism, what is the mathematical expression that relates correctly angle x with the other shown angles in the figure?




ⓐ $x = a + d$  ⓑ $x = a - b$

ⓒ $x = b - c$  ⓓ $x = b + c$

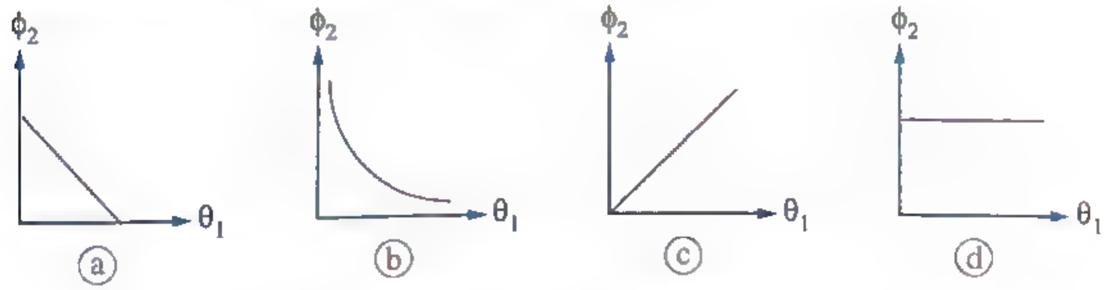
2 In the opposite figure, which angle represents the apex angle of the prism when calculating the deviation angle of the light ray?




ⓐ Angle x  ⓑ Angle y

ⓒ Angle z  ⓓ Any of them

3 Which of the following graphs represents the relation of the second angle of incidence ($\phi_2$) versus the angle of refraction ($\theta_1$) for a light ray that gets incident on the face of a triangular prism with different angles of incidence?




4 The following three physical quantities are related to the deviation of light in a triangular prism:

(I) The apex angle of the prism

(II) The refractive index of the prism's material for the used light

(III) The angle of deviation

So, on which of these quantities does the second angle of incidence in the triangular prism depend?

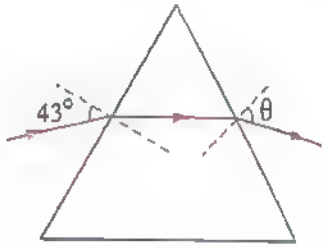
(a) (I), (II) (b) (I), (III)

(c) (II), (III) (d) (I), (II), (III)

5 * A ray of light falls on a triangular glass prism at an angle of incidence of 45° and emerges with an angle of 52°. If the refractive index of the prism material is 1.5, then its apex angle equals ............ .

(a) 28.13° (b) 30.18° (c) 31.69° (d) 59.82°

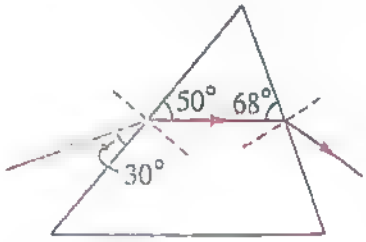
6 * The opposite figure shows the path of a light ray through an equilateral triangular prism of refractive index 1.5, so the value of angle θ equals ............ .




(a) 47.2° (b) 43°

(c) 54.8° (d) 27°

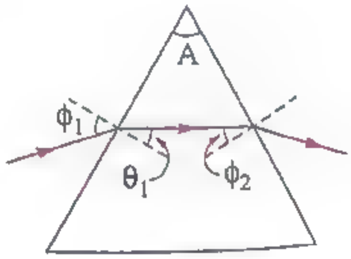
7 * The opposite figure shows the path of a light ray through a triangular prism, then the angle of deviation for the ray equals ............ .




(a) 22° (b) 28.38°

(c) 30° (d) 30.38°

8 In the opposite figure, what is the effect of increasing the angle of incidence ($\phi_1$) on the angle of refraction ($\theta_1$) and the second angle of incidence ($\phi_2$)?



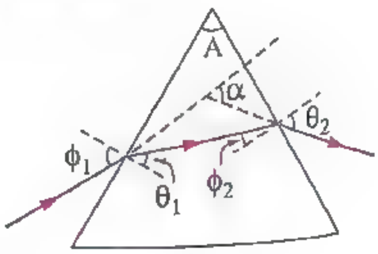

(a) Both angles increase.

(b) Both angles decrease.

(c) $\theta_1$ increases and $\phi_2$ decreases.

(d) $\theta_1$ decreases and $\phi_2$ increases.

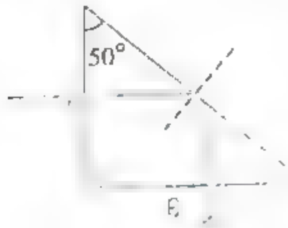
9 * In the opposite figure, if $\phi_1 > \theta_2$ and $\alpha = A$, so the angle of incidence ($\phi_1$) could be equal to ............ .




(a) $\frac{1}{2}$ A (b) A

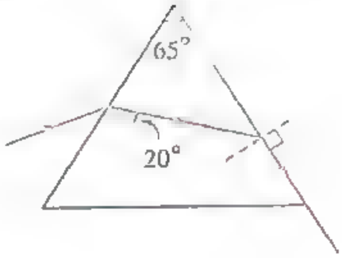
(c) $\frac{4}{3}$ A (d) 2 A

10 In the opposite figure, if the refractive index of the prism's material is 1.5, then the value of angle θ almost equals ……… .



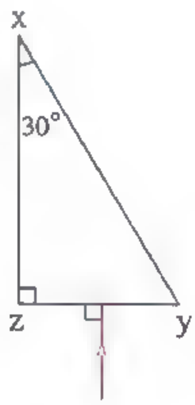

ⓐ 20° ⓑ 18°
ⓒ 15° ⓓ 10°

11 The opposite figure represents the path of a light ray through a triangular prism, hence the deviation angle of the light ray equals ……… .



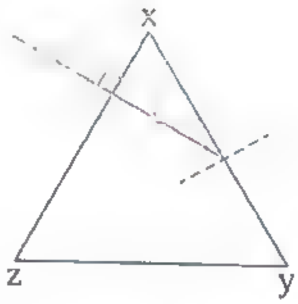

ⓐ 65° ⓑ 53.9°
ⓒ 45° ⓓ 28.9°

12 In the opposite figure, a ray falls perpendicularly on face yz of a triangular prism. If the critical angle of the prism's material is 42°, which statement of the following is correct?



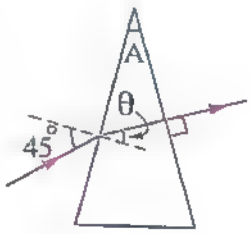

ⓐ The ray passes through face yz without deviation.
ⓑ The angle of incidence of the ray on face xy equals 60°
ⓒ The ray gets reflected totally on face xy.
ⓓ All the previous.

13 ✻ In the opposite figure, a light ray is incident normally on face xz of an equilateral triangular prism whose refractive index is $\sqrt{2}$, hence the ray ……… .



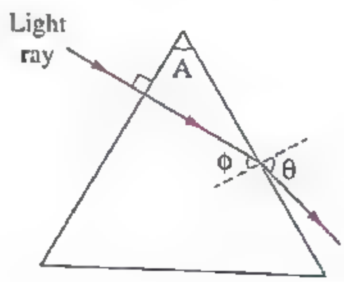

ⓐ emerges from face xy
ⓑ emerges from face xz
ⓒ deviates from its path by an angle of 120°
ⓓ deviates from its path by an angle of 60°

14 In the opposite figure, the apex angle (A) of the prism is ……… .



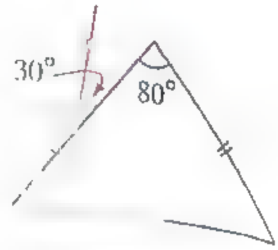

ⓐ greater than 45° ⓑ less than 45°
ⓒ equal to 45° ⓓ indeterminable

15 In the opposite figure, the apex angle (A) of the prism is ………




ⓐ greater than angle θ ⓑ less than angle θ
ⓒ greater than angle ϕ ⓓ less than angle ϕ

16 ✱ The opposite figure shows a light ray falling on one of the faces of an isosceles triangular prism which is made of a material of refractive index 1.5, then the angle of deviation of the ray equals ..........




ⓐ 14.74° ⓑ 22.44° ⓒ 32.44° ⓓ 50.2°

17 ✱ A light ray falls normally on one of the faces of a triangular prism of apex angle 30°. If the refractive index of the prism is $\sqrt{2}$, then:

(i) The angle of emergence of the ray from the prism equals ............ .

ⓐ 15° ⓑ 30° ⓒ 45° ⓓ 60°

(ii) The angle of deviation of the ray equals ............ .

ⓐ 15° ⓑ 30° ⓒ 45° ⓓ 60°

18 ✱ If a ray of light falls perpendicularly on one of the faces of a triangular prism of apex angle 45° and emerges as a tangent to the other face, then the refractive index of the prism's material is ............ .

ⓐ 1.2 ⓑ $\sqrt{3}$ ⓒ $\sqrt{2}$ ⓓ $2\sqrt{2}$

19 ✱ The apex angle of a triangular prism is 30°, a light ray falls perpendicularly on one of its faces, so it gets deviated by an angle that equals 20°, so the refractive index of the prism material is ............ .

ⓐ 1.25 ⓑ 1.44 ⓒ 1.53 ⓓ 1.66

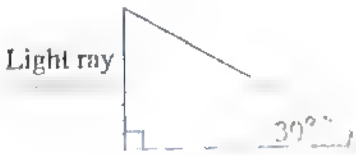
20 ✱ A light ray falls at an angle of incidence 60° on one of the faces of a triangular prism whose apex angle is 40°, to emerge perpendicular from the other face, then the refractive index of the prism is ............ .

ⓐ 1.35 ⓑ 1.29 ⓒ 1.21 ⓓ 1.13

21 ✱ A ray of light falls from air on the face of a triangular glass prism whose apex angle is 72°. If the ray gets refracted by an angle of 30° and emerged tangent to the other face, then the critical angle between glass and air is ............ .

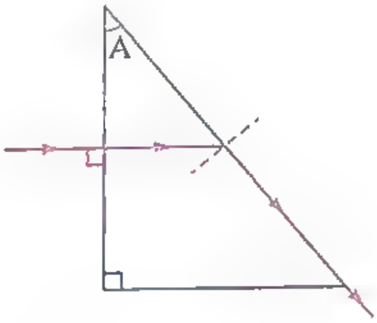
ⓐ 30° ⓑ 42° ⓒ 48° ⓓ 60°

22 * In the opposite figure, if the refractive index of the prism is 1.5, so the emergence angle of the light ray from the prism equals ............ .



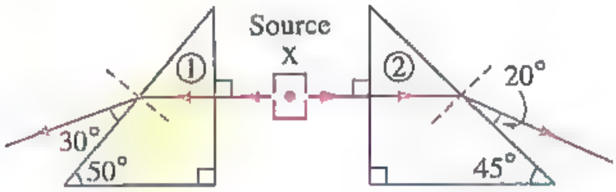

(a) 19.47°  (b) 41.81°  (c) 48.59°  (d) 60°

23 In the opposite figure, a light ray passes through a triangular prism of a transparent material with a speed that equals 0.8 c where c is the speed of light in air, so angle A is approximately equal to ............ .




(a) 37°  (b) 40°
(c) 50°  (d) 53°

24 * Two light rays are emitted from source x to pass through two prisms (1) and (2) of different materials of refractive indices $n_1$ and $n_2$ respectively as shown in the opposite figure, hence the relation between these refractive indices is ............

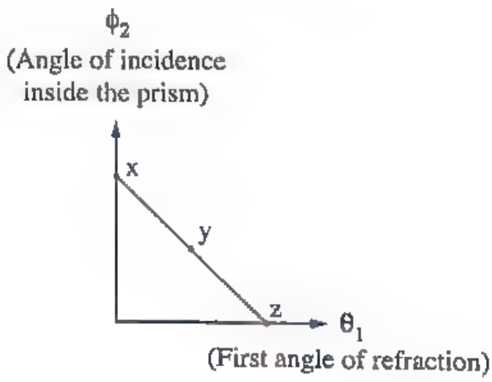



(a) $n_1 < n_2$  (b) $n_2 < n_1$
(c) $n_1 = n_2 \neq 1$  (d) $n_1 = n_2 = 1$

25 Which of the following angles in an equilateral triangular prism whose material has a refractive index of 1.5 could have possible values of 0° or 90°?

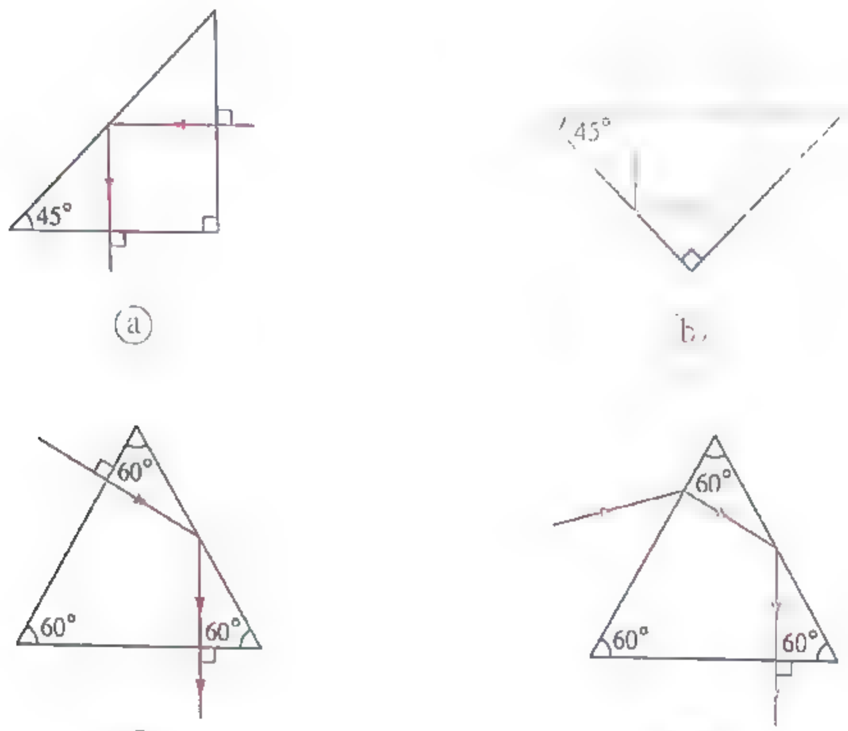
(a) The deviation angle ($\alpha$).
(b) The second angle of incidence ($\phi_2$).
(c) The angle of refraction ($\theta_1$).
(d) The angle of emergence ($\theta_2$).

26 In the opposite graph, which of the shown points represents the state of a light ray that is incident normal on one of the faces of a triangular prism?



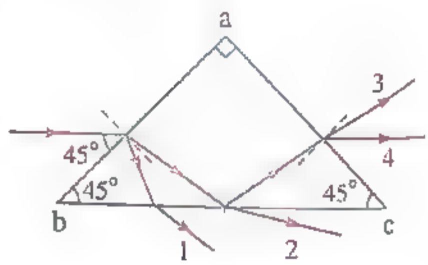

(a) Point x  (b) Point y
(c) Point z  (d) None of them

27 In which of the following cases the path of the light ray is not represented correctly, given that the refractive index of the material of the triangular prisms in all cases equals 1.5?



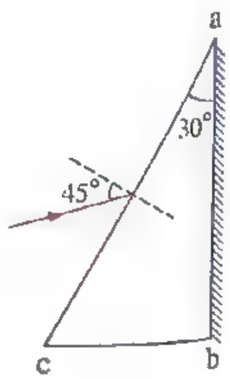

(a) (b) (c) (d)

28 In the opposite figure, a light ray is incident at an angle of 45° on one of the faces an isosceles right angled triangular prism whose material refractive index is 1.5, so the correct path of the emerged light ray is ............ .



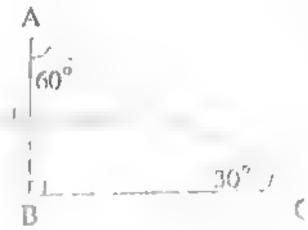

(a) 1
(b) 2
(c) 3
(d) 4

29 ✱ A triangular glass prism abc, whose face ab is silvered, has an apex angle of 30° as in the figure. If a light ray falls at an angle of 45° on face ac, the ray gets refracted inside the prism then it gets reflected on the silvered face and retraces its path, so the refractive index of the prism equals ............ .




(a) $\frac{\sqrt{2}}{2}$ (b) $\sqrt{2}$
(c) $\frac{\sqrt{6}}{3}$ (d) $\frac{\sqrt{6}}{2}$

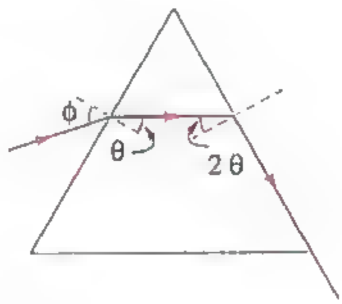
30 ✻ The opposite figure shows a prism of refractive index 1.5 submerged in a liquid of refractive index n. If a light ray falls perpendicular on the face AB and emerges tangential to face AC, so the value of n equals ............ .




ⓐ $\frac{2\sqrt{3}}{3}$ ⓑ $\frac{5}{3}$

ⓒ $\frac{4}{3}$ ⓓ $\frac{3\sqrt{3}}{4}$

31 ✻ The opposite figure shows a light ray falling on an equilateral triangular prism. If the ray emerges tangentially from the opposite face of the prism, then the angle of incidence ($\phi$) equals ..........

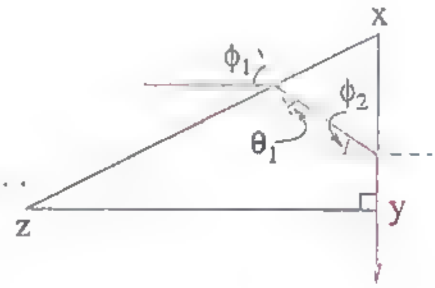



ⓐ 45.52° ⓑ 36.24°

ⓒ 32.25° ⓓ 27.22°

32 ✻ The opposite figure shows the path of a light ray which falls on face xz of a right triangular prism.

If $xy = \frac{1}{2}yz$, $\theta_1 = \frac{1}{2}\phi_2$, then:




(i) The refractive index of the prism's material equals .......... .

ⓐ 1.11 ⓑ 1.35

ⓒ 1.49 ⓓ 1.51

(ii) The angle of deviation equals .......... .

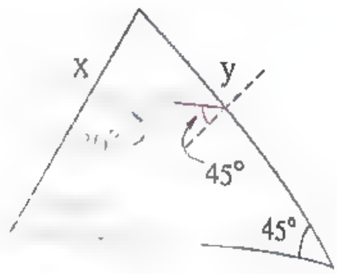
ⓐ 32.51° ⓑ 59.08°

ⓒ 63.43° ⓓ 90°

33 ✻ A triangular prism has an apex angle 60° and refractive index $\sqrt{3}$, so the minimum angle of incidence of a ray on one of the faces of the prism that makes the ray emerge from the other face of the prism is .......... .

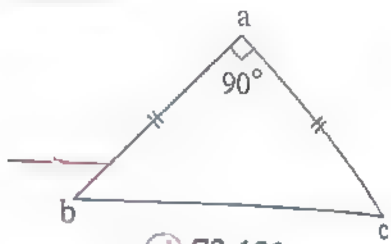
ⓐ 32.32° ⓑ 37.37° ⓒ 42.42° ⓓ 46.46°

34 ✳ In the opposite figure, if the critical angle of the prism's material is 42°, then the values of the first angle of incidence and the angle of emergence respectively are ............ , ............ .



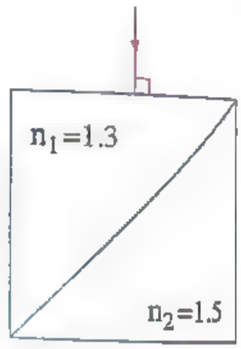

(a) 60°, 90°
(b) 60°, 0°
(c) 48.16°, 0°
(d) 48.16°, 90°

35 ✳ The opposite figure shows a light ray falling parallel to the base on the face of a right angled triangular glass prism whose refractive index is 1.5, then the angle of emergence equals ........... .



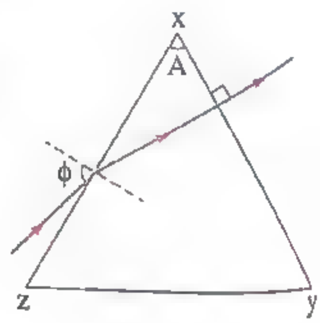

(a) 28.13°
(b) 45°
(c) 60°
(d) 73.13°

36 ✳ In the opposite figure, a light ray falls from air normal to the face of a cube that is formed of two different kinds of glass, then its angle of emergence from this cube is .......... .



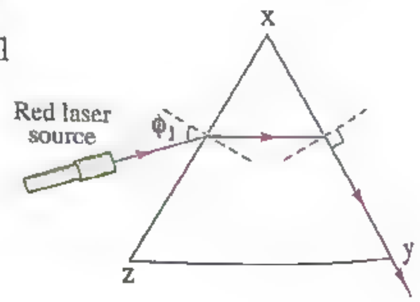

(a) 7.21°
(b) 10.85°
(c) 37.79°
(d) 45°

37 In the opposite figure, a light ray is incident on a glass triangular prism of refractive index 1.5 that is surrounded by air, so when reducing the angle of incidence (ϕ) by 5°, the light ray ............ .



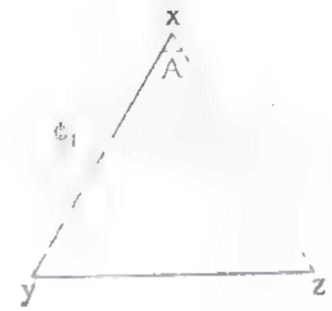

(a) emerges from face xy refracted away from the normal
(b) emerges from face xy refracted towards the normal
(c) emerges from face xy tangent to the interface
(d) undergoes total internal reflection from face xy

38 In the opposite figure, if the red laser source is required to be changed with a blue laser source, yet the light ray is still wanted to emerge tangent to the face of the prism, what should be done to the angle of incidence $\phi_1$?




(a) It should be increased.
(b) It should be decreased.
(c) It shouldn't be changed.
(d) The answer is indeterminable.

39 * A light ray is incident in air with an angle of incidence $\phi_1$ on one of the faces of a triangular prism of apex angle A and refractive index n as shown in the opposite figure, which of the following modif [illegible] internal reflection at face xz?




(a) Increasing the angle of incidence $\phi_1$

(b) Decreasing the angle of incidence $\phi_1$

(c) Using another prism of the same material with a smaller apex angle A

(d) Using another prism of a material with a refractive index smaller than n

40 When a light ray emerges from a triangular prism tangent to the opposite face of the face on which the ray is incident in the first, the angle of deviation ($\alpha$) for the light ray ............. .

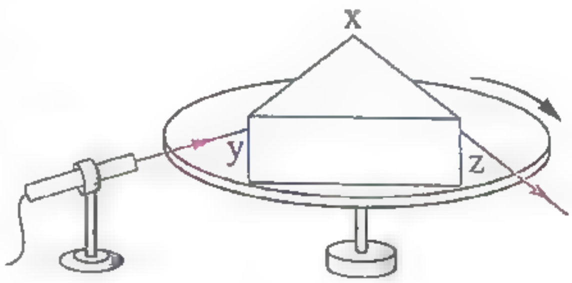
(a) equals 0°

(b) equals 90°

(c) lies outside the prism

(d) has the least minimum value

41 The opposite figure represents a triangular prism (xyz) placed on a rotatable disk in which a laser light ray is incident on face xy and emerges tangent to face xz, so when the disk is rotated slightly in the clockwise direction, the laser light ray at face xz will ............. .




(a) emerge with an angle smaller than 90°

(b) emerge tangent to face yz

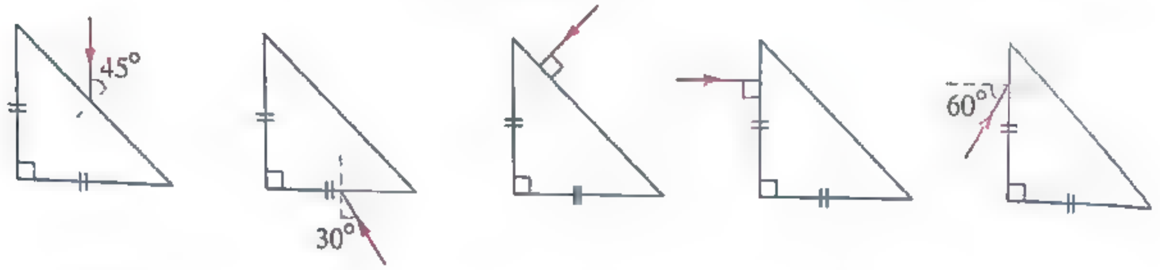
(c) undergo total internal reflection inside the prism

(d) emerge normal to face xz

## Second Essay questions

1. **What** are the factors on which the angle of deviation of the light ray in the triangular prism depends?

2. The following figures show five different cases of the falling of a light ray on one of the faces of a right angled isosceles triangular prism of refractive index 1.5




(1) (2) (3) (4) (5)

**In which of these figures the following actions happen? Illustrate your answer with drawings.**

(a) The ray deviates with an angle 90°.

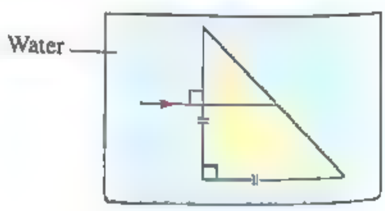
(b) The ray emerges from the same face of its incidence.

(c) The ray suffers total internal reflection twice inside the prism.

(d) The ray emerges by an angle 30°.

3. In the opposite figure:

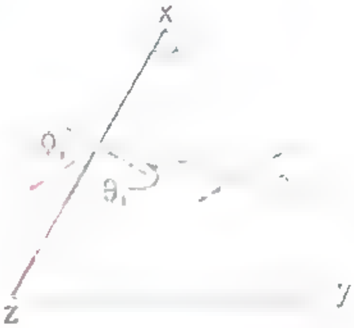
**Trace** the path of the incident light ray till it emerges from the prism, where the critical angle of the prism's material with air is 42° and the absolute refractive index of water is 1.33.



# New Types of questions

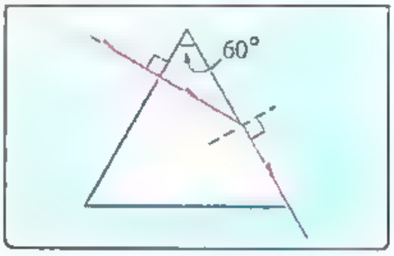
Understand Apply Higher Order Thinking Skills

**First : Choose two correct answers in each of the following :**




1. In the opposite figure, a light ray passes through a triangular prism, so when $\phi_1$ increases, ...

(a) $\theta_2$ decreases
(b) $\theta_2$ remains constant
(c) $\theta_1$ decreases
(d) $\theta_1$ increases
(e) the ray undergoes total internal reflection at face xy




2. In the opposite figure, an equilateral triangular prism of material refractive index 1.5 is immersed in a liquid of refractive index n. A light ray is incident perpendicular on one of the prism faces to emerge tangent to the opposite face, so ............ .

(a) the refractive index of the liquid (n) equals $\sqrt{2}$
(b) the refractive index of the liquid (n) equals $\sqrt{3}$
(c) the refractive index of the liquid (n) equals $\frac{3\sqrt{3}}{4}$
(d) the angle of deviation of the ray equals 60°
(e) the angle of deviation of the ray equals 30°

**Second: Use the figure to complete the blanks:**

Put in front of each of the following sentences the change happening to the angle of incidence $\phi_1$ (increase or decrease) that leads to the occurrence of each of the following :

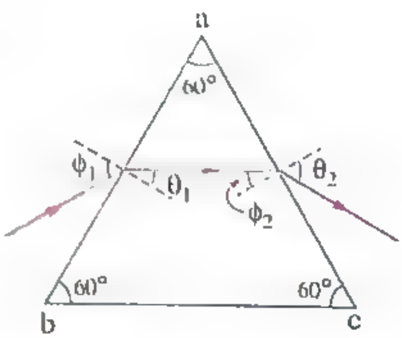
(1) Increasing the angle of refraction ($\theta_1$) (..........)

(2) Increasing the second angle of incidence ($\phi_2$) (..........)

(3) Increasing the angle of emergence ($\theta_2$) (..........)

(4) The light ray won't emerge from face ac as it undergoes a total internal reflection (..........)

(5) The emergence of the ray normal to face ac (..........)



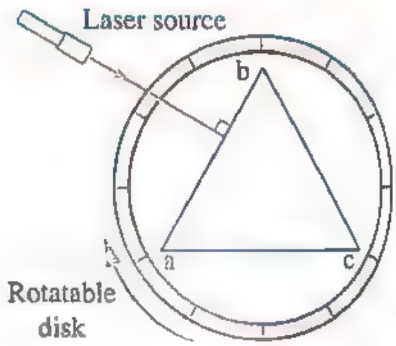

Chapter 2

Lesson Five

# Minimum Deviation in a Triangular Prism and Thin Prism

## The minimum angle of deviation in the triangular prism

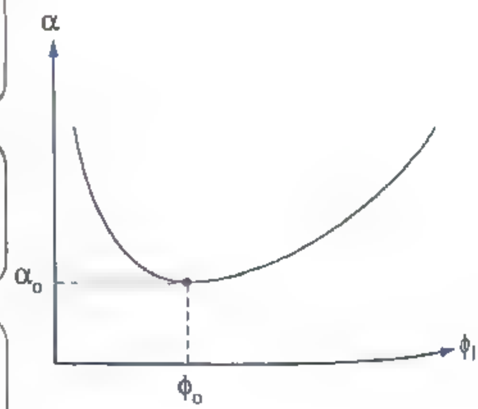
⊙ The opposite figure represents the incidence of a light ray perpendicularly on face ab of a triangular prism abc that is placed on a rotatable disk, so if the disk has been rotated to increase the angle of incidence of the light ray ($\phi_1$), then measuring the angle of emergence from face bc multiple times and after that calculating the angle of deviation ($\alpha$) each time from the relation:




$$\alpha = \phi_1 + \theta_2 - A$$

**Then, when plotting a graph of deviation angle ($\alpha$) versus the first angle of incidence ($\phi_1$) for the light ray, we find that:**

1. At a small angle of incidence ($\phi_1$), the angle of deviation ($\alpha$) will be large and as the first angle of incidence ($\phi_1$) increases, the angle of deviation ($\alpha$) decreases.
2. At a certain angle of incidence ($\phi_o$), the angle of deviation reaches its minimum value ($\alpha_o$), hence in this case the prism becomes in the minimum deviation position.
3. By increasing the first angle of incidence ($\phi_1$) above its value at the minimum deviation position, the angle of deviation ($\alpha$) increases again.



- **It was found that at minimum deviation position:**

The angle of emergence ($\theta_2$) = The angle of incidence ($\phi_1$) = $\phi_o$

The second angle of incidence ($\phi_2$) = The angle of refraction ($\theta_1$) = $\theta_o$

## Calculat[illegible] deviation [illegible]

**When the triangular prism is being in the minimum deviation position, then**

| | |
|---|---|
| $\phi_1 = \theta_2 = \phi_o$ | $\theta_1 = \phi_2 = \theta_o$ |
| $\because \alpha = \phi_1 + \theta_2 - A$ | $\because A = \theta_1 + \phi_2$ |
| $\therefore \alpha_o = 2\,\phi_o - A$ | $\therefore A = 2\,\theta_o$ |
| $\therefore \phi_o = \frac{\alpha_o + A}{2}$ | $\therefore \theta_o = \frac{A}{2}$ |

**Applying Snell's law:**

$$n_{medium} \sin\phi_o = n_{prism} \sin\theta_o$$

**So, if the medium surrounding the prism is:**

| Air | Another medium other than air |
|---|---|
| $\therefore n_{prism} = \frac{\sin\phi_o}{\sin\theta_o}$ | $\therefore \frac{n_{prism}}{n_{medium}} = \frac{\sin\phi_o}{\sin\theta_o}$ |
| $\therefore n_{prism} = \frac{\sin\left(\frac{\alpha_o + A}{2}\right)}{\sin\left(\frac{A}{2}\right)}$ | $\therefore \frac{n_{prism}}{n_{medium}} = \frac{\sin\left(\frac{\alpha_o + A}{2}\right)}{\sin\left(\frac{A}{2}\right)}$ |

## The relation between the second angle of incidence ($\phi_2$) and the angle of refraction ($\theta_1$) in a triangular prism:

⊙ The first angle of refraction ($\theta_1$) and the second angle of incidence ($\phi_2$) are related by the relation:

$$A = \theta_1 + \phi_2$$

$$\therefore \phi_2 = A - \theta_1$$

Since, the apex angle (A) is constant for the same prism, so as $\theta_1$ increases, $\phi_2$ decreases and the relation between them $(\theta_1, \phi_2)$ can be represented as follows:


- x: $\phi_1 = \theta_1 = 0$ , $\phi_2 = A$
  The light ray falls perpendicular to the face of the prism
- y: $\phi_1 = \theta_2$ , $\theta_1 = \phi_2$
  The prism is at the minimum deviation position
- z: $\phi_2 = \theta_2 = 0$ , $\theta_1 = A$
  The light ray emerges perpendicularly from the prism's face

◉ **The factors on which the angle of minimum deviation ($\alpha_0$) depends in a triangular prism:**

**1** The apex angle of the prism (A) :

As The apex angle of the prism (A) → Increases, → The minimum angle of deviation ($\alpha_0$) → Increases

**2** The refractive index of the prism's material for the used light (n) :

As The refractive index of the prism's material for the used light (n) → Increases, → The minimum angle of deviation ($\alpha_0$) → Increases

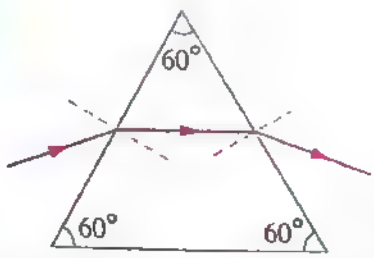
**3** The wavelength of the used light (λ) :

As The wavelength of the used light (λ) → Decreases, → The minimum angle of deviation ($\alpha_0$) → Increases

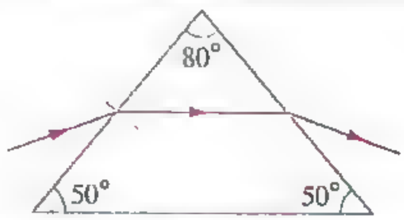
## Note:

- In the minimum deviation position, the light ray inside the triangular prism will be parallel to the base if the prism is:

**1** Equilateral




**2** Isosceles
(for the two sides through which the ray enters and emerges)



## ① Test yourself

Choose the correct answer:

In which of the following cases the prism is in the minimum deviation position?


### Example 1

*A triangular prism is made of a material whose refractive index is $\sqrt{2}$ having an apex angle that equals 60°, calculate:*

*(a)* The minimum angle of deviation in the prism.

*(b)* The angle of incidence and the angle of emergence at minimum deviation.

**Solution**

$n = \sqrt{2}$ ; $A = 60°$ ; $\alpha_0 = ?$ ; $\phi_1 = ?$ ; $\theta_2 = ?$

$$(a)\ n = \frac{\sin\left(\frac{\alpha_0 + A}{2}\right)}{\sin\left(\frac{A}{2}\right)} \quad , \quad \sqrt{2} = \frac{\sin\left(\frac{\alpha_0 + 60}{2}\right)}{\sin\left(\frac{60}{2}\right)}$$

$$\sin\left(\frac{\alpha_0 + 60}{2}\right) = \frac{\sqrt{2}}{2}$$

$$\frac{\alpha_0 + 60}{2} = 45° \quad , \quad \alpha_0 = 30°$$

$$(b)\ \phi_1 = \theta_2 = \phi_0 = \frac{\alpha_0 + A}{2} = \frac{30 + 60}{2} = 45°$$

**What if** the light ray falls on the prism with an angle greater than the angle that has been calculated in the example, **what happens to** the deviation angle of the ray?

### Example 2

*A triangular prism has an apex angle of 60°. If the first angle of incidence equals double the angle of refraction at the minimum deviation of a red light ray through that prism, calculate the minimum angle of deviation.*

## Solution

$A = 60°$ $\phi_o = 2\,\theta_o$ $\alpha_o = ?$

When the triangular prism is in the minimum deviation position

$$\phi_o = \frac{\alpha_o + A}{2} \quad , \quad \theta_o = \frac{A}{2}$$

$$\because \phi_o = 2\,\theta_o$$

$$\therefore \frac{\alpha_o + A}{2} = 2\left(\frac{A}{2}\right)$$

$$\therefore \alpha_o + A = 2\,A$$

$$\therefore \alpha_o = 2\,A - A = A = 60°$$

**What if** a blue light ray falls on the prism instead of the red ray, **what will happen to** the value of the angle of minimum deviation through the same prism?

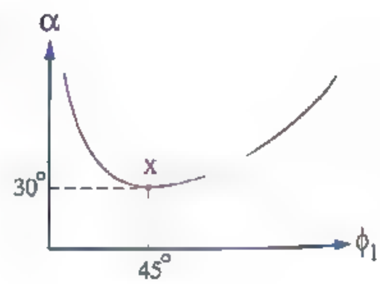
## Example 3

*The opposite graph represents the relation between the angle of deviation ($\alpha$) for a light ray passing through a triangular prism and the first angle of incidence ($\phi_1$) on the face of the prism, calculate:*

*(a)* The apex angle of the prism.

*(b)* The refractive index of the prism.

*(c)* The angle of emergence from the prism at point x.




## Solution

*(a)* Point x represents the position of minimum deviation in the prism:

$$\phi_o = \frac{\alpha_o + A}{2}$$

$$\therefore A = 2\,\phi_o - \alpha_o$$

$$= (2 \times 45) - 30$$

$$= 60°$$

*(b)* $$n = \frac{\sin\left(\frac{\alpha_o + A}{2}\right)}{\sin\left(\frac{A}{2}\right)} = \frac{\sin\left(\frac{30+60}{2}\right)}{\sin\left(\frac{60}{2}\right)} = \sqrt{2}$$

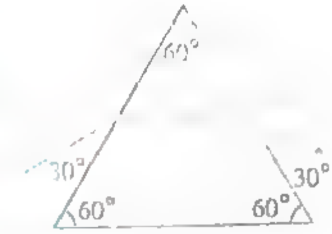
### *Another Solution:*

$$\theta_o = \frac{A}{2} = \frac{60}{2} = 30° \quad , \quad n = \frac{\sin\phi_o}{\sin\theta_o} = \frac{\sin 45}{\sin 30} = \sqrt{2}$$

*(c)* $\theta_2 = \phi_1 = \phi_o = 45°$

## Example 4

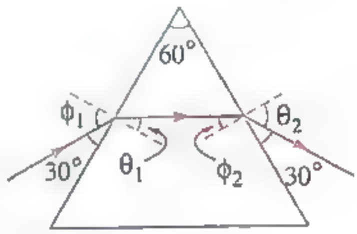
*The opposite figure represents the path of a light ray through a triangular prism, so the refractive index of the prism's material equals .*




ⓐ $\sqrt{2}$ ⓑ 1.5 ⓒ $\sqrt{3}$ ⓓ 1.33

### Solution

From the figure, we find:




$\phi_1 = 90 - 30 = 60°$

$\theta_2 = 90 - 30 = 60°$

$\therefore \phi_1 = \theta_2$

$\therefore$ The prism is in the minimum deviation position.

$\therefore \theta_1 = \phi_2 = \frac{A}{2} = \frac{60}{2} = 30°$

$\therefore n = \frac{\sin \phi_1}{\sin \theta_1} = \frac{\sin 60}{\sin 30} = \sqrt{3}$

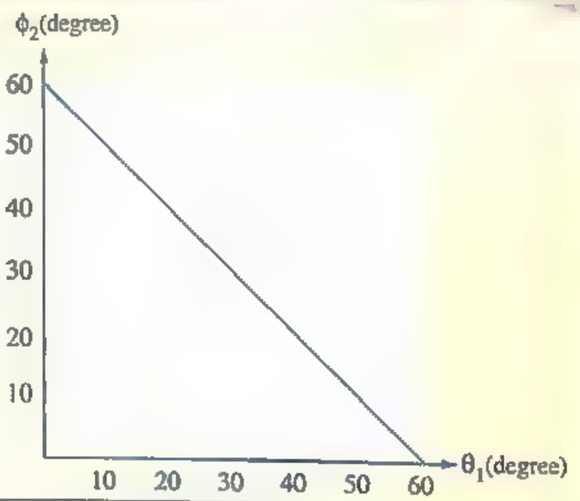
$\therefore$ **The correct choice is ⓒ.**

**What if** the prism has a greater apex angle and the incident ray falls with the same angle on its face, **what will happen to** the deviation angle of the ray?

## 2 Test yourself

**1** ✻ The opposite graph depicts the relation between the second angle of incidence ($\phi_2$) and the angle of refraction ($\theta_1$) in a triangular prism of refractive index 1.5

**Calculate** the angle of minimum deviation.

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**2** **Choose the correct answer :**

The angle with which a light ray is incident on the face of a prism that has an apex angle of 60° and a material's index of refraction of $\sqrt{3}$ to pass through the prism with the minimum possible angle of deviation equals .............. .

ⓐ 30° ⓑ 45° ⓒ 60° ⓓ 75°

**3** **Could** a light ray fall on a triangular prism two times with two different angles of incidence and deviate in both times with the same angle of deviation ($\alpha$)?

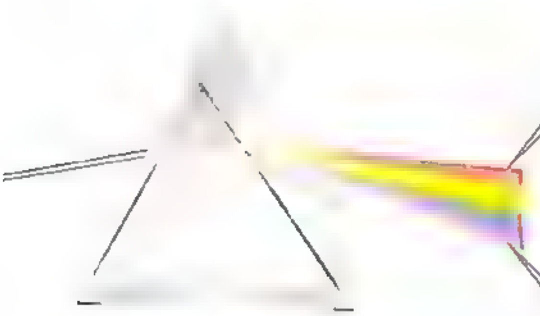
## Dispersion of light by the triangular prism

Visible (white) light consists of a range of wavelengths that extends nearly from 400 nm to 700 nm, hence if a beam of white light falls on a triangular prism in the minimum deviation position, it emerges from the prism separated into a spectrum of colors which can be assigned to seven colors of spectrum which can be listed as their order from the apex to the base of the prism as follows:

**Red** → **Orange** → **Yellow** → **Green** → **Blue** → **Indigo** → **Violet**

**Explaining the dispersion of light by a triangular prism:**

As the wavelength ($\lambda$) of light increases, the index of refraction (n) which this light encounters at entering the prism decreases, hence the angle of deviation ($\alpha$) of a ray of that light through the prism decreases, therefore we find:



**Red** light has the least angle of deviation because it has the longest wavelength and as ($n \propto \frac{1}{\lambda}$), red light encounters the least value of refractive index for the prism and the **smallest deviation.**

**Violet** light has the largest angle of deviation because it has the shortest wavelength and hence it has the largest refractive index and the **largest deviation.**

- The dispersion of light happens distinctly when the prism is set in minimum deviation position.

## Thin prism

⊙ It is a triangular prism that is made of a transparent material (like glass) and has a very small apex angle that does not exceed 10° and it is always in the position of minimum deviation.

▸ **Some concepts related to the thin prism**

1. **Deviation angle**
2. **Angular dispersion**
3. **Dispersive power**

# 1 Deviation angle

## Deducing the deviation angle in the thin prism

$\because$ The thin prism is always in the position of minimum deviation when it is surrounded by air.

$\therefore$ When the thin prism is surrounded by air, the refractive index (n) of its material can be determined from the relation:

$$n = \frac{\sin\left(\frac{\alpha_o + A}{2}\right)}{\sin\left(\frac{A}{2}\right)}$$

$\because \frac{\alpha_o + A}{2}, \frac{A}{2}$ are small angles, then the sine of these angles is approximately equal to their angles in radians.

$$\therefore n = \frac{\frac{\alpha_o + A}{2}}{\frac{A}{2}} = \frac{\alpha_o + A}{A}$$

**Notice that** the ratio between the angles in radians equals the ratio between them in degrees.

$\therefore \alpha_o + A = An$ $\qquad \therefore \boxed{\alpha_o = A(n-1)}$

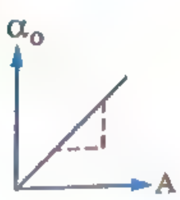
When the thin prism is put in any other medium other than air, the angle of deviation will be determined from the relation:

$$\boxed{\alpha_o = A\left(\frac{n_{prism}}{n_{medium}} - 1\right)}$$

## The factors on which the angle of deviation ($\alpha_o$) in the thin prism depends (when the prism is in air)

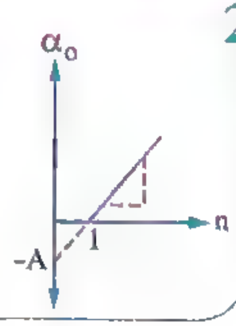
**1** The apex angle of the thin prism "directly proportional"

Slope $= \frac{\Delta \alpha_o}{\Delta A} = n - 1$




**2** The refractive index of the prism material for the used light

Slope $= \frac{\Delta \alpha_o}{\Delta n} = A$




$\alpha_o = A(n-1)$

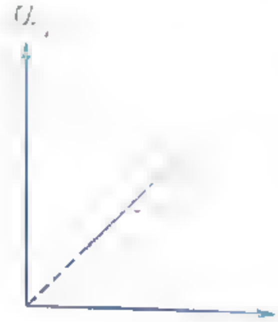
## Notes:

(1) $\alpha_o$ in the thin prism doesn't depend on the first angle of i[illegible] it doesn't exceed 10°.

(2) The angle of deviation in the thin prism depends on the wav[illegible] incident light ($\lambda$).

(3) When plotting a graph of deviation angle ($\alpha_o$) for multiple thin prisms that have equal apex angles versus $(n - 1)$, the opposite graph will be obtained where:

$$\text{Slope} = \frac{\Delta \alpha_o}{\Delta (n-1)} = A$$




(4) To convert the value of an angle from degrees into radians and vice versa, we use the following relation:

$$\boxed{\frac{\theta_{rad}}{\pi} = \frac{\theta_{deg}}{180}}$$

And from the opposite table, we find that the sine of small angles ($\sin \theta$) equals approximately the values of these angles in radians ($\theta_{rad}$):

| $\theta_{deg}$ | 90° | 60° | 30° | 10° | 4° | 1° |
|---|---|---|---|---|---|---|
| $\sin \theta$ | 1 | 0.87 | 0.5 | 0.1736 | 0.0698 | 0.017 |
| $\theta_{rad}$ | 1.57 | 1.05 | 0.52 | 0.1745 | 0.0698 | 0.017 |

$\theta_{rad} \simeq \sin \theta$

(At small angles)

**Example 1**

***A thin prism has an apex angle of 7° and refractive index of 1.5. Calculate the angle of deviation of light in the prism.***

**Solution**

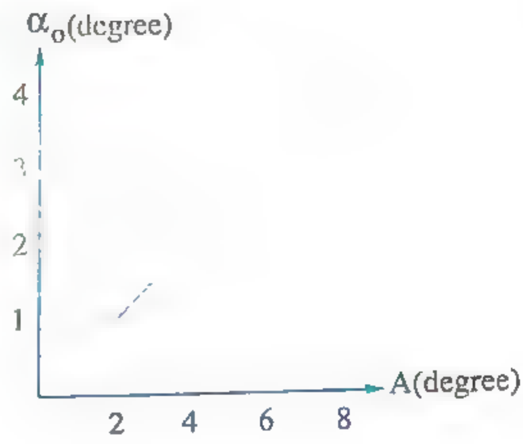
$A = 7^\circ$ $\quad n = 1.5$ $\quad \alpha_o = ?$

$\alpha_o = A(n - 1)$

$= 7 \times (1.5 - 1) = 3.5^\circ$

## Example 2

*The opposite graph depicts the relation between the deviation angle ($\alpha_o$) of a light ray through multiple thin prisms which are made of the same material and the apex angle (A) for these prisms, calculate the refractive index of the material of which the prisms are made.*




### Solution

$$\text{Slope} = \frac{\Delta\alpha_o}{\Delta A} = \frac{4-2}{8-4} = 0.5$$

$\because \alpha_o = A(n-1)$

$\therefore \text{Slope} = n - 1 = 0.5$

$\therefore n = 1.5$

## Example 3

*When a red light ray fell on a thin prism of apex angle A and refractive index n, the ray deviated by an angle of 4°. If the prism has been submerged in a liquid of refractive index 1.2, the angle of deviation becomes 2°.*

*Calculate:*

*(a)* The absolute refractive index of the prism (n).

*(b)* The apex angle of the prism (A).

### Solution

$(\alpha_o)_1 = 4^\circ$ ; $n_{liquid} = 1.2$ ; $(\alpha_o)_2 = 2^\circ$ ; $n = ?$ ; $A = ?$

*(a)*

**Before submerging the prism in the liquid**

$(\alpha_o)_1 = A(n-1)$

$4 = A(n-1)$ (1)

**After submerging the prism in the liquid**

$(\alpha_o)_2 = A\left(\frac{n}{n_{liquid}} - 1\right)$

$2 = A\left(\frac{n}{1.2} - 1\right)$ (2)

By dividing equation (1) by equation (2):

$$\frac{4}{2} = \frac{A(n-1)}{A\left(\frac{n}{1.2}-1\right)}$$

$$2\left(\frac{n}{1.2} - 1\right) = n - 1$$

$$\frac{2n}{1.2} - 2 = n - 1$$

$\therefore n = 1.5$

*(b)* By substituting with the value of n in equation (1) :

$4 = A(1.5 - 1)$ $\therefore A = 8°$

## 3 Test yourself

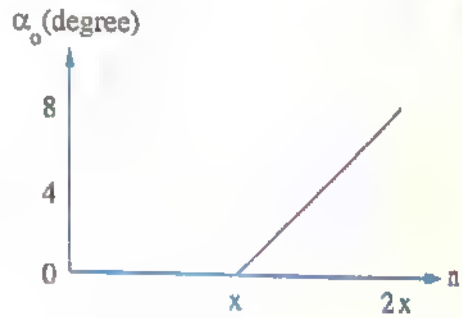
**Choose the correct answer:**

1. A laser beam falls on a thin prism at multiple angles of incidence ($\phi_1$), then in which of the following cases does the largest angle of deviation appear?

   (a) $\phi_1 = 4°$ (b) $\phi_1 = 5°$

   (c) $\phi_1 = 6°$ (d) All of them have the same deviation angle.

2. The opposite graph represents the relation between the angles of deviation ($\alpha_o$) and the refractive index (n) for multiple thin prisms that have equal apex angles (A), so the values of x and A are ............... .

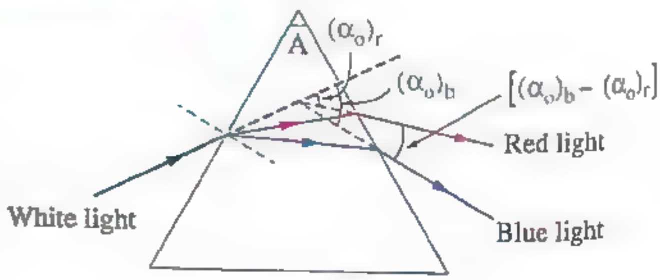



| | x | A |
|---|---|---|
| (a) | 8 | 8 |
| (b) | 1 | 4 |
| (c) | 1 | 8 |
| (d) | 8 | 4 |

## 2 Angular dispersion

### Deducing the angular dispersion in thin prism

$\because$ The thin prism is always in the position of minimum deviation and the angle of deviation ($\alpha_o$) depends on the refractive index (n) of the thin prism for the falling light ray which in turn depends on the wavelength ($\lambda$) of the falling light ray.




$\therefore$ The angle of deviation ($\alpha_o$) of the light ray changes by changing the wavelength ($\lambda$) of the ray, so the thin prism disperses the white light into the visible spectral colors, where we can determine:

| ⓫ **The angle of deviation of the red light** | **The angle of deviation of the blue (violet) light** |
|---|---|
| (the least angle of deviation for the colors of visible light) | (the largest angle of deviation for the colors of visible light) |

**From the relation**

| | |
|---|---|
| $(\alpha_o)_r = A(n_r - 1)$ (1) | $(\alpha_o)_b = A(n_b - 1)$ (2) |

**Where**

| | |
|---|---|
| $(n_r)$ is the prism's refractive index for red light | $(n_b)$ is the prism's refractive index for blue light |

$\because n_b > n_r \qquad \therefore (\alpha_o)_b > (\alpha_o)_r$

By subtracting the two previous equations (1) and (2), we get the value of the angle between the two emergent rays (blue and red): $(\alpha_o)_b - (\alpha_o)_r = A(n_b - 1) - A(n_r - 1)$

$$\therefore \quad (\alpha_o)_b - (\alpha_o)_r = A(n_b - n_r)$$

⊙ The value $[(\alpha_o)_b - (\alpha_o)_r]$ is called the angular dispersion between the blue and the red rays.

**The angular dispersion :**

It is the angle between the extensions of the red and blue rays after their emergence from the thin prism.

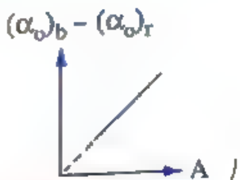
Or

It is the difference between the deviation angles of red and blue lights in the thin prism.

## The factors on which the angular dispersion depends

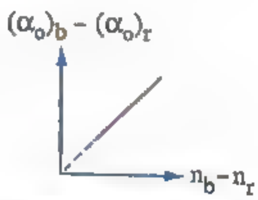
❶ The apex angle of the prism (A) "directly proportional"

$$\text{Slope} = \frac{\Delta[(\alpha_o)_b - (\alpha_o)_r]}{\Delta A} = n_b - n_r$$




❷ The prism's refractive indices for both blue and red lights $(n_b - n_r)$

$$\text{Slope} = \frac{\Delta[(\alpha_o)_b - (\alpha_o)_r]}{\Delta(n_b - n_r)} = A$$




$$(\alpha_o)_b - (\alpha_o)_r = A(n_b - n_r)$$

## Note:

- Yellow light is considered the intermediate between the blue and red lights, so we can define:

**The average refractive index ($n_y$):**
It is the refractive index of yellow light ($n_y$).

**The average angle of deviation $(\alpha_o)_y$:**
It is the angle of deviation of yellow light $(\alpha_o)_y$

**From the relation**

$$n_y = \frac{n_b + n_r}{2}$$

$$(\alpha_o)_y = \frac{(\alpha_o)_b + (\alpha_o)_r}{2}$$

## 3 Dispersive power

- Each transparent material if shaped as a thin prism have a characteristic dispersive power that distinguishes a material from another and it can be defined as follows:

**The dispersive power ($\omega_\alpha$) :**
It is the ratio of the angular dispersion between blue and red lights to the angle of deviation for the yellow light (the average angle of deviation).

### Deducing the dispersive power

$\because (\alpha_o)_b - (\alpha_o)_r = A\,(n_b - n_r)$ , $\because (\alpha_o)_y = A\,(n_y - 1)$

$$\therefore \omega_\alpha = \frac{(\alpha_o)_b - (\alpha_o)_r}{(\alpha_o)_y} = \frac{A\,(n_b - n_r)}{A\,(n_y - 1)}$$

$$\therefore \omega_\alpha = \frac{n_b - n_r}{n_y - 1} = \frac{n_b - n_r}{\left(\frac{n_b + n_r}{2}\right) - 1}$$

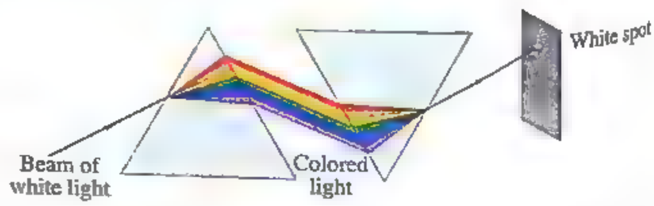
**Where:** ($n_y$) is the refractive index of the prism for yellow.
**Notice that** dispersive power ($\omega_\alpha$) is dimensionless
***i.e.***, has no measuring unit because it is a ratio between two quantities of the same type.

### The factors on which the dispersive power of a thin prism depends:

The prism's material refractive index only not on the apex angle of the prism nor the light angle of incidence on it.

## Note:

- **A rectangular glass block does not disperse light** because it acts as two similar reversed triangular prisms; one counteracts the dispersion of the other.



## Example 1

*A thin prism has an apex angle of 8°, its refractive index for red light is 1.52 and its refractive index for blue light is 1.54 . Calculate:*

*(a)* The angle of deviation for each light color.

*(b)* The angular dispersion for the light in the prism.

*(c)* The dispersive power of the prism.

## Solution

$A = 8^\circ$ $\quad n_r = 1.52$ $\quad n_b = 1.54$ $\quad (\alpha_o)_b = ?$ $\quad (\alpha_o)_r = ?$

$(\alpha_o)_b - (\alpha_o)_r = ?$ $\quad \omega_\alpha = ?$

*(a)* $(\alpha_o)_b = A(n_b - 1) = 8 \times (1.54 - 1) = 4.32^\circ$

$(\alpha_o)_r = A(n_r - 1) = 8 \times (1.52 - 1) = 4.16^\circ$

*(b)* $(\alpha_o)_b - (\alpha_o)_r = 4.32 - 4.16 = 0.16^\circ$

### Another Solution:

$(\alpha_o)_b - (\alpha_o)_r = A(n_b - n_r) = 8 \times (1.54 - 1.52) = 0.16^\circ$

*(c)* $n_y = \frac{n_b + n_r}{2} = \frac{1.54 + 1.52}{2} = 1.53$

$\omega_\alpha = \frac{n_b - n_r}{n_y - 1} = \frac{1.54 - 1.52}{1.53 - 1} = 0.038$

**What if** a white light ray falls on this prism for one time with an angle of 30° and for another time with an angle of 60°, **in which** of the two cases is the dispersive power in the prism greater?

## Example 2

*Two thin prisms have equal angular dispersions, the first prism is made of flint glass of average refractive index 1.6 and dispersive power 0.036, while the second prism is made of crown glass of average refractive index 1.5 and dispersive power 0.028. If the apex angle of the second prism is 7°, calculate the apex angle of the first prism.*

**Solution**

$(n_y)_1 = 1.6$ $\quad (\omega_\alpha)_1 = 0.036$ $\quad (n_y)_2 = 1.5$ $\quad (\omega_\alpha)_2 = 0.028$ $\quad A_2 = 7°$ $\quad A_1 = ?$

$\because \omega_\alpha = \frac{n_b - n_r}{n_y - 1}$ $\qquad \therefore n_b - n_r = \omega_\alpha (n_y - 1)$

- In the first prism:

$$(n_b)_1 - (n_r)_1 = (\omega_\alpha)_1 \left((n_y)_1 - 1\right) = 0.036 \times (1.6 - 1) = 0.0216$$

- In the second prism:

$$(n_b)_2 - (n_r)_2 = (\omega_\alpha)_2 \left((n_y)_2 - 1\right) = 0.028 \times (1.5 - 1) = 0.014$$

$\because$ They have the same angular dispersion:

$$\therefore A_1 \left((n_b)_1 - (n_r)_1\right) = A_2 \left((n_b)_2 - (n_r)_2\right)$$

$\therefore A_1 \times 0.0216 = 7 \times 0.014$ $\qquad \therefore A_1 = \frac{7 \times 0.014}{0.0216} = 4.54°$

**What if** you are asked to calculate the apex angle of a prism of flint glass that causes the same deviation angle for yellow light as that caused by the second prism, **what** will be your answer?

## 4 Test yourself

Answered

**1** ✱ A thin prism has an apex angle of 10°, refractive index for red light 1.52 and for blue light 1.58. **Calculate** the angular dispersion and the dispersive power of the prism.

..................................................................................................................................

..................................................................................................................................

..................................................................................................................................

**2** **Choose the correct answer:**

Two thin prisms x and y are made of the same material, the apex angle of prism x is A and its dispersive power is $\omega_\alpha$, so if the apex angle of prism y is 1.5 A, its dispersive power is ................ .

(a) $\frac{\omega_\alpha}{2}$ (b) $\omega_\alpha$ (c) $2\ \omega_\alpha$ (d) $3\ \omega_\alpha$

**From the previous, we can compare between the normal prism and the thin prism as follows:**

| | The normal prism | The thin prism |
|---|---|---|
| **The apex angle (A)** | Large (more than 10°) | Small (less than 10°) |
| **The refractive index (n)** | $n = \frac{\sin \phi_1}{\sin \theta_1} = \frac{\sin \theta_2}{\sin \phi_2}$ | $n = \frac{\alpha_o + A}{A}$ |
| **The angle of deviation ($\alpha$)** | $\alpha = \phi_1 + \theta_2 - A$ | $\alpha_o = A(n-1)$<br>Always at the minimum deviation angle |
| **The minimum deviation position** | One of the positions at which the triangular prism can be set in which its refractive index is given by:<br>$n = \frac{\sin\left(\frac{\alpha_o + A}{2}\right)}{\sin\left(\frac{A}{2}\right)}$ | Always in the position of minimum deviation where the angle of deviation is determined from the relation:<br>$\alpha_o = A(n-1)$ |
| **Uses** | - Spectral dispersion of light into its components of wavelengths.<br>- As a reflecting prism in some optical devices such as periscope and binocular. | Dispersion of light into its components of wavelengths. |

Chapter 2

Questions on Lesson Five

# Minimum Deviation in a Triangular Prism and Thin Prism

To watch videos of how to solve questions use the App

معاك

Ma3ak App

Interactive test

The questions signed by ✻ are answered in detail.

Higher Order Thinking Skills

## First

### Triangular prism at minimum deviation

**1** When the prism is being in the minimum deviation position, the refractive index of the prism is determined from the relation; .............

ⓐ $n = \dfrac{\sin \phi_1}{\sin \theta_2}$  ⓑ $n = \dfrac{\sin \dfrac{(\alpha_o + A)}{2}}{\dfrac{\sin A}{2}}$  ⓒ $n = \dfrac{\sin \phi_1}{\sin \phi_2}$  ⓓ $n = \dfrac{\sin A}{\sin \alpha}$

---

**2** ✻ If the deviation angle for a light ray that passes through an equilateral triangular prism in the minimum deviation position is 30°, then:

(i) The angle of incidence of the ray on the prism face equals ............. .

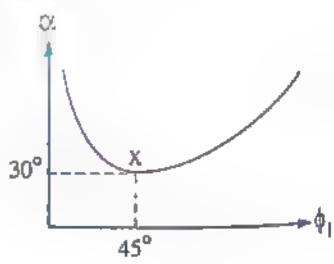
ⓐ 30°  ⓑ 45°  ⓒ 60°  ⓓ 90°

(ii) The emergence angle of the ray from the prism equals ............. .

ⓐ 90°  ⓑ 60°  ⓒ 45°  ⓓ 30°

---

**3** ✻ The opposite graph shows the relation between the angle of deviation ($\alpha$) and the first angle of incidence ($\phi_1$) for a light ray on one of the faces of a triangular prism, so:




(i) The apex angle of the prism equals ........... .

ⓐ 30°  ⓑ 45°

ⓒ 60°  ⓓ 90°

(ii) The absolute refractive index of the prism material equals ............. .

ⓐ 1.5  ⓑ $\sqrt{2}$  ⓒ 1.33  ⓓ $\sqrt{3}$

(iii) The emergence angle of the ray at the position of x equals ............. .

ⓐ 30°  ⓑ 37°  ⓒ 45°  ⓓ 75°

---

**4** ✻ A triangular prism has an apex angle of 60° and a refractive index of $\sqrt{2}$, then the angle of deviation and the angle of incidence at the minimum deviation position respectively are ............. .

ⓐ 30°, 45°  ⓑ 45°, 30°  ⓒ 60°, 45°  ⓓ 45°, 60°

**5** If a light ray is incident on an equilateral triangular prism and undergoes the minimum deviation, the second angle of incidence inside the prism equals ............. .

(a) 30° (b) 45° (c) 60° (d) 90°

**6** ✱ A light ray is incident on an equilateral triangular prism, if the angle of incidence = The angle of emergence = 40°, then:

**(i)** The angle of deviation of the light ray equals ............. .

ⓐ 20° ⓑ 40° ⓒ 60° ⓓ 80°

**(ii)** The refractive index of the prism's material equals ............. .

ⓐ 1.1 ⓑ 1.15 ⓒ 1.29 ⓓ 1.53

**7** ✱ A glass prism in which a light ray has deviated with an angle that equals its first angle of incidence that equals 60° has an apex angle of 60°, so the refractive index of the prism's material equals ............. .

ⓐ $\sqrt{2}$ ⓑ $\frac{1}{\sqrt{2}}$ ⓒ $\sqrt{3}$ ⓓ $\frac{1}{\sqrt{3}}$

**8** A light ray is incident with an angle $\phi_1$ on one of the faces of an equilateral triangular prism, hence it gets refracted by an angle of 30°, what happens to the deviation angle of the light ray ($\alpha$) when increasing or decreasing the angle of incidence ($\phi_1$) by 5°?

| | Increasing $\phi_1$ | Decreasing $\phi_1$ |
|---|---|---|
| ⓐ | Deviation increases | Deviation decreases |
| ⓑ | Deviation increases | Deviation increases |
| ⓒ | Deviation decreases | Deviation decreases |
| ⓓ | Deviation decreases | Deviation increases |

**9** The ratio between the refractive index of the material of a triangular prism for violet light and the refractive index of the material of the same prism for red light $\left(\frac{n_{violet}}{n_{red}}\right)$ is ............ .

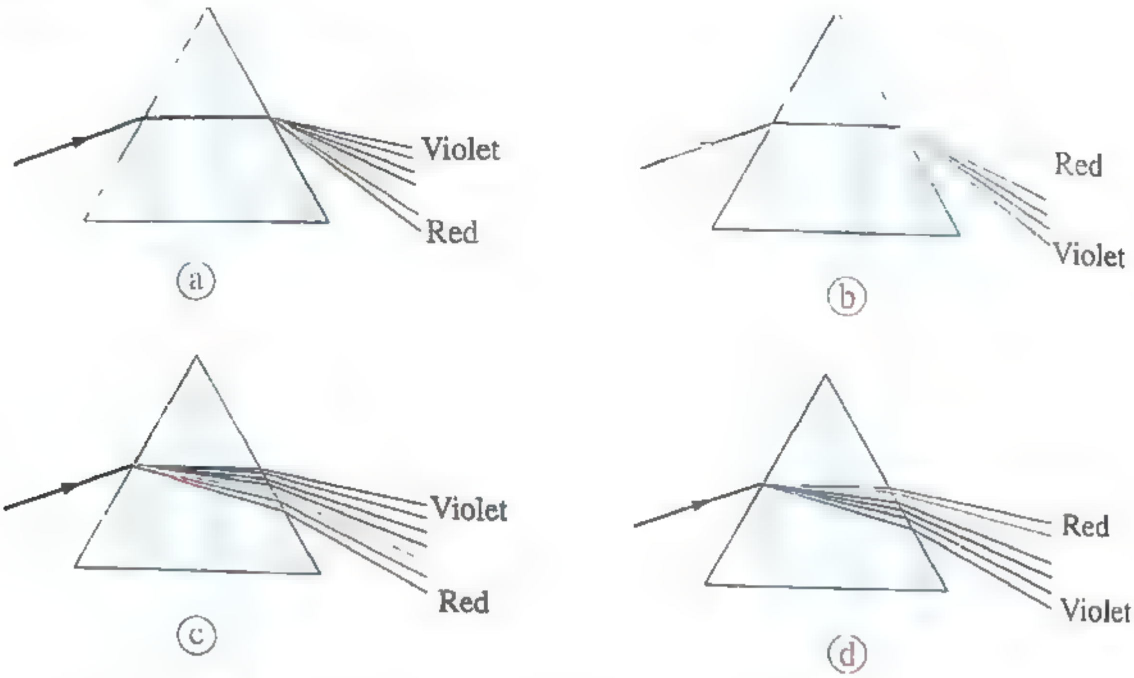
ⓐ greater than one ⓑ less than one ⓒ equal to one ⓓ indeterminable

**10** On increasing the wavelength of an incident light ray on one of the faces of a triangular prism in minimum deviation position, the minimum deviation angle ............. .

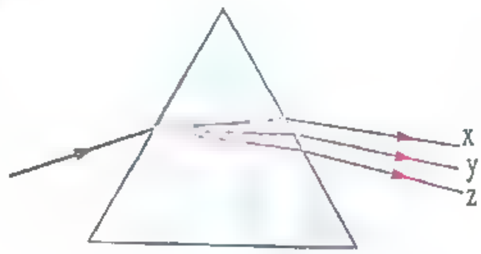
ⓐ increases ⓑ decreases

ⓒ doesn't change ⓓ cannot be determined

11. If a narrow beam of white light falls on one of the faces of a triangular prism set in the minimum deviation position, which of the following figures shows how this beam of light disperses?

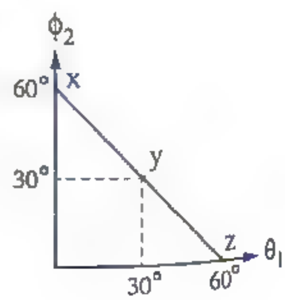



12. The opposite figure represents the dispersion of white light by a glass prism, so the light rays x, y and z might have the colors of ............ .




| | x | y | z |
|---|---|---|---|
| (a) | Blue | Yellow | Red |
| (b) | Red | Blue | Yellow |
| (c) | Red | Yellow | Blue |
| (d) | Yellow | Red | Blue |

13. The opposite graph shows the relation between the second angle of incidence ($\phi_2$) and the first angle of refraction ($\theta_1$) of a light ray falling into a triangular prism. If the angle of minimum deviation is 30°, so:



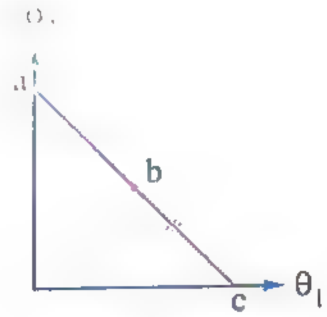

(i) The refractive index of the prism equals ............ .

(a) $\sqrt{2}$ (b) 1.48
(c) $\sqrt{3}$ (d) 1.55

(ii) The angle of emergence of the light ray from the prism when it is in the minimum deviation position equals ............ .

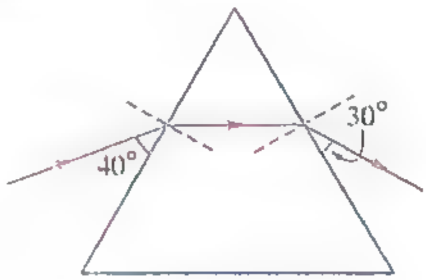
(a) 15°   (b) 30°   (c) 45°   (d) 60°

**14** ✱ The opposite graph represents the relation between the second angle of incidence ($\phi_2$) and the first angle of refraction ($\theta_1$) when a light ray passes through an equilateral triangular prism, so the position of minimum deviation is represented by point ............ .



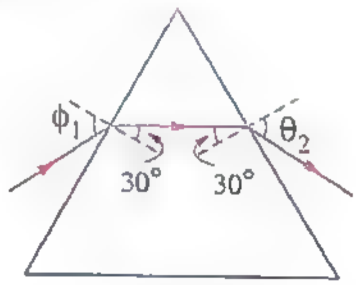

(a) a   (b) b   (c) c   (d) both a and c

**15** What is the possible value of the angle of deviation for the light ray that passes through the prism shown in the opposite figure if the minimum angle of deviation through that prism is 45°?



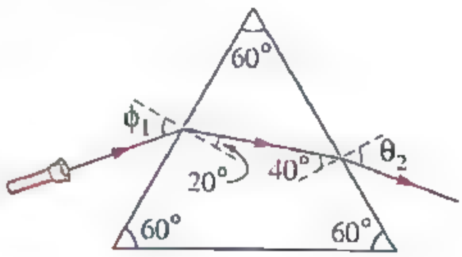

(a) 22.5°   (b) 30°   (c) 45°   (d) 50°

**16** The opposite figure shows a triangular prism where a light ray falls on its face at an angle $\phi_1$ and emerges from the other face at an angle $\theta_2$, so the ratio $\frac{\sin \phi_1}{\sin \theta_2}$ equals ............ .



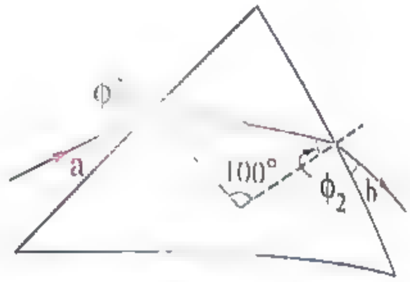

(a) $\frac{1}{2}$   (b) $\frac{1}{1}$   (c) $\frac{1}{\sqrt{2}}$   (d) $\frac{1}{\sqrt{3}}$

**17** In the opposite figure, to set the prism in the minimum deviation position, we have to ............ .




(a) increase the angle of incidence ($\phi_1$)
(b) direct the light ray normal onto the face of the prism
(c) increase the angle of incidence ($\phi_2$)
(d) direct the light ray tangent onto the face of the prism

18 ✳ The opposite figure shows a light ray falling on one of the faces of a triangular prism at an angle $\phi_1$, if $\hat{a} = \hat{b}$ and $\phi_1 = 1.5\ \phi_2$, then:




(i) The apex angle of the prism equals ............. .

ⓐ 20° ⓑ 60° ⓒ 80° ⓓ 100°

(ii) The first angle of incidence ($\phi_1$) equals ............. .

ⓐ 20° ⓑ 40° ⓒ 60° ⓓ 80°

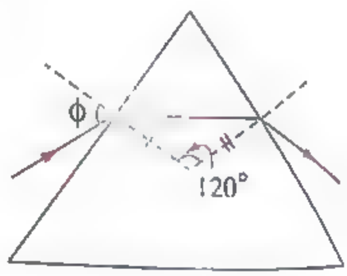
(iii) The refractive index of the prism equals ............. .

ⓐ 1.05 ⓑ 1.14 ⓒ 1.35 ⓓ 1.53

19 ✳ A triangular prism has an apex angle that equals 1.5 $\alpha_o$, where $\alpha_o$ is the minimum deviation angle for the prism while the prism becomes in minimum deviation position when a light ray falls on one of its faces with an angle of incidence of 50°, hence the refractive index of the prism equals ............. .

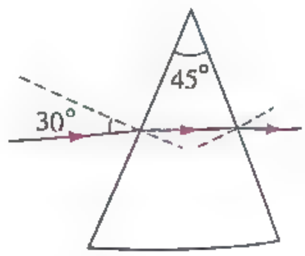
ⓐ 1.25 ⓑ 1.42 ⓒ 1.53 ⓓ 1.73

20 ✳ If the opposite figure shows the deviation of a light ray through a prism of refractive index $\sqrt{3}$, so ............ .




| | The first angle of incidence ($\phi$) | The angle of deviation ($\alpha$) |
|---|---|---|
| ⓐ | 30° | 30° |
| ⓑ | 30° | 60° |
| ⓒ | 60° | 30° |
| ⓓ | 60° | 60° |

21 ✳ The opposite figure shows an isosceles triangular prism, having an apex angle of 45° and made of a transparent material. If a light ray falls on one of its faces at an angle of 30° and gets refracted inside the prism parallel to the base, then:




(i) The angle of emergence of the light ray from the prism equals ............. .

ⓐ 15° ⓑ 30° ⓒ 45° ⓓ 60°

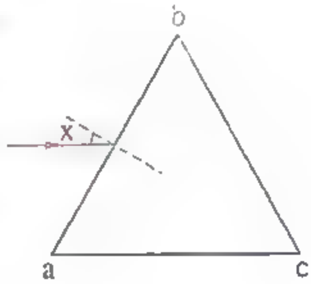
(ii) The angle of deviation of the light ray equals ............ .

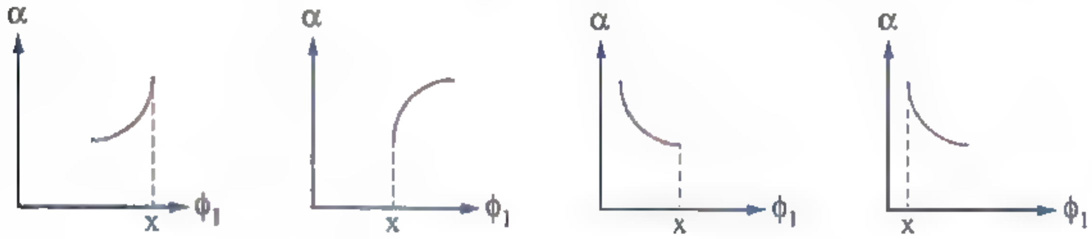
(a) 60° (b) 45° (c) 30° (d) 15°

(iii) The refractive index of the prism equals ............ .

(a) 1.22 (b) 1.27 (c) 1.31 (d) 1.6

22 A light ray is incident with angle x on the face of a triangular prism abc as shown in the opposite figure, hence the ray encounters the least possible deviation as it emerges from face bc, so which of the following graphs will represent the change in the angle of deviation of the light ray versus the change in the angle of incidence?




(a) (b) (c) (d)

23 ✱ The apex angle of a triangular prism is 60° and its refractive index is 1.5. If it's submerged in a liquid whose refractive index is 1.3, then:

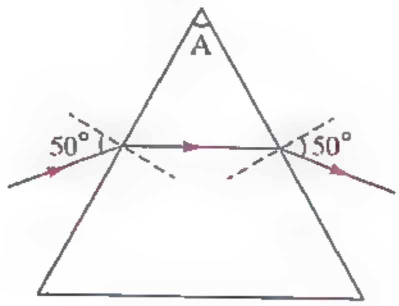
(i) The minimum angle of deviation will equal ............ .

(a) 8.46° (b) 9.64° (c) 10.2° (d) 35.1°

(ii) The first angle of incidence in the position of minimum deviation will equal ............ .

(a) 34.3° (b) 35.1° (c) 47.5° (d) 60°

24 The opposite figure shows the path of a light ray that is incident with an angle of 50° on a triangular prism of a material refractive index n, if the prism is submerged in a liquid of refractive index 0.9 n, then the light ray is set to be incident on the same face with the same angle, the angle of deviation of the ray ............ .



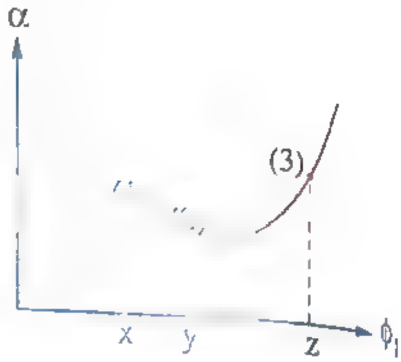

(a) will increase

(b) will decrease

(c) might increase or decrease

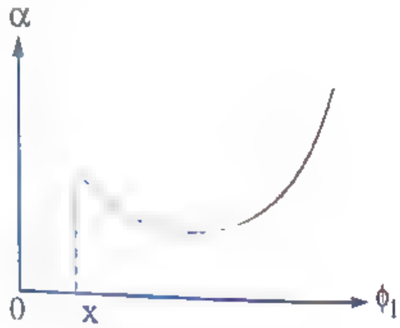
(d) won't change

**25** If three light rays (1), (2) and (3) are incident on a triangular prism with angles of incidence x, y and z respectively such that the relation between the deviation angle ($\alpha$) and the angle of incidence ($\phi_1$) is as shown in the opposite graph, so the angle of emergence of ray (1) compared to the angle of emergence of each of ............ .




| | Ray (2) | Ray (3) |
|---|---|---|
| ⓐ | greater | smaller |
| ⓑ | greater | greater |
| ⓒ | smaller | smaller |
| ⓓ | smaller | greater |

**26** The opposite graph represents the relation between the angle of deviation ($\alpha$) of a light ray through a triangular prism and the angle of incidence ($\phi_1$) of the ray. When the ray is incident with angle x on the face of the prism, it emerges tangent to the opposite face, so if the ray is incident with an angle that is $0 < \phi_1 < x$, the ray at the opposite face ............ .




ⓐ emerges perpendicular
ⓑ emerges tangent
ⓒ encounters total internal reflection
ⓓ retraces its path

### Thin prism

**27** A thin prism has an apex angle of 5° and refractive index of 1.6, so the deviation angle of light through it equals ............ .

ⓐ 3° ⓑ 5° ⓒ 6° ⓓ 8°

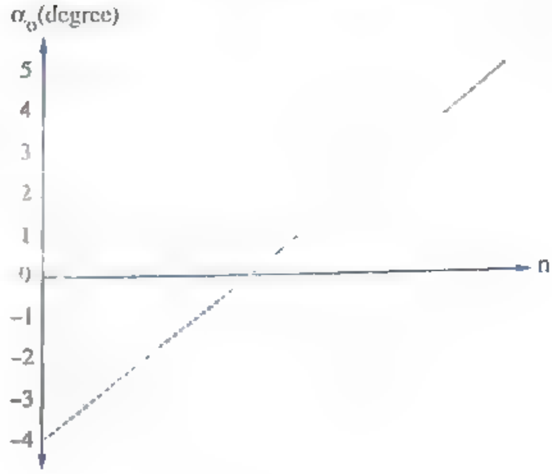
**28** If the angle of deviation of a light ray in a thin prism equals its apex angle, the refractive index of the prism equals ............ .

ⓐ 1 ⓑ 2 ⓒ $\frac{\sqrt{2}}{2}$ ⓓ $\sqrt{2}$

29 ✻ The opposite figure represents the relation variation of the angle of deviation ($\alpha_o$) for a light ray in different thin prisms with equal apex angles versus the refractive index (n) for the materials of these prisms, then the apex angle of the prisms equals ............. .

ⓐ 4° ⓑ 5°

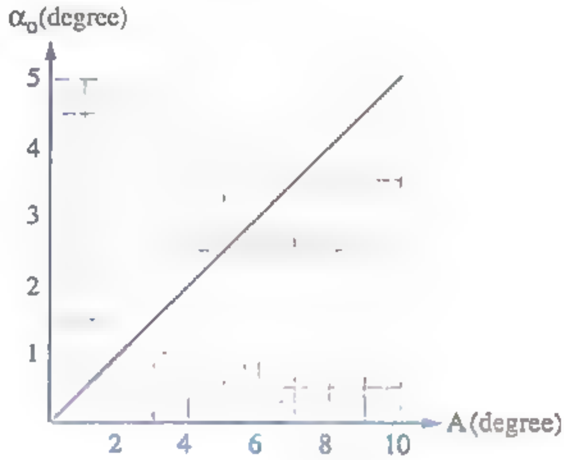
ⓒ 6° ⓓ 7°




30 ✻ The opposite graph depicts the relation between the angle of deviation of light ($\alpha_o$) in different thin prisms that are made of the same material and the apex angles (A) of each of them, so the refractive index of the prism's material equals ............. .

ⓐ 1.2 ⓑ 2

ⓒ $\sqrt{2}$ ⓓ 1.5




31 ✻ Two thin prisms are placed inverted to each other such that one of them cancels the deviation which is initiated by the other. The apex of the first prism equals 8° and its refractive index is 1.5. If the apex angle of the second prism is 6°, then its refractive index is .......... .

ⓐ 1.08 ⓑ 1.125 ⓒ 1.67 ⓓ 2.22

32 ✻ Thin prism of apex angle 10° and refractive index of its material 1.6 is submerged in a liquid of refractive index 1.25, then the deviation angle of a light ray through the prism is .......... .

ⓐ 2.5° ⓑ 2.8° ⓒ 3.5° ⓓ 6°

33 A light ray deviates from its path with an angle α when it passes through a glass thin prism surrounded by air, so when this prism is submerged in water, the angle of deviation of the light ray through it becomes ............. .

ⓐ α ⓑ greater than α ⓒ less than α ⓓ zero

**34** ✱ A thin prism has an apex angle 8°, a refractive index 1.4 for red light and 1.6 for blue light, then the average angle of deviation for white light through it equals ........ .

ⓐ 16° ⓑ 12° ⓒ 8° ⓓ 4°

**35** A thin prism has an apex angle of 6°. If its refractive index for blue light is 1.65 and for red light is 1.6, so the angular dispersion between blue light and red light through the prism equals .......... .

ⓐ 0.1° ⓑ 0.2° ⓒ 0.3° ⓓ 0.5°

**36** A thin prism with an apex angle of 10° is made of a material of refractive index for red light 1.5 and for yellow light 1.55, so the dispersive power of the prism equals ............ .

ⓐ $\frac{11}{13}$ ⓑ $\frac{10}{33}$ ⓒ $\frac{2}{11}$ ⓓ $\frac{22}{37}$

**37** If the sum of the refractive indices of blue and red light of a thin prism is 3.1 and the difference between them is 0.1, so the dispersive power of the prism is .......... .

ⓐ 1.1 ⓑ 0.2 ⓒ 0.18 ⓓ 0.14

**38** ✱ A white light falls on the face of a thin glass prism whose apex angle is 8°, the refractive index of its material for blue and red lights are 1.7 and 1.5 respectively, then:

(i) The deviation angles of the red and blue rays equal .......... .

| | The deviation angle of the red ray | The deviation angle of the blue ray |
|---|---|---|
| ⓐ | 12° | 13.6° |
| ⓑ | 12° | 5.6° |
| ⓒ | 4° | 5.6° |
| ⓓ | 4° | 13.6° |

**(ii)** The angular dispersion of light in the prism equals ...... ......

ⓐ 25.6° ⓑ 13.6° ⓒ 12° ⓓ 1.6°

**(iii)** The dispersive power of the prism equals ..........

ⓐ 0.08 ⓑ 0.125 ⓒ 0.33 ⓓ 3.2

39 * If you have two thin prisms, the refractive indices for red light and blue light in the first prism are 1.48 and 1.56 respectively and for the second one are 1.63, 1.69 respectively, so the ratio between the dispersive power of the first prism and that of the second prism $\frac{(\omega_\alpha)_1}{(\omega_\alpha)_2}$ is ......

ⓐ $\frac{11}{13}$ ⓑ $\frac{13}{11}$ ⓒ $\frac{22}{13}$ ⓓ $\frac{13}{22}$

40 * Two thin prisms have the same angular dispersion, one of them is made of crown glass, has an apex angle of 6.25°, an average refractive index 1.5 and a dispersive power of 0.048. If the other is made of flint glass where it has an apex angle of 10° and dispersive power of 0.024, then the average refractive index of the second prism equals .........

ⓐ 2.93 ⓑ 2.62 ⓒ 1.625 ⓓ 1.125

## Second Essay questions

1 **What happens when** a beam of white light falls on a triangular prism adjusted in the minimum deviation position?

2 **Explain the following statements:**

(1) In the same triangular prism the angle of minimum deviation changes by the change of the wavelength of the passing light through it.

(2) When white light falls on a triangular prism, the deviation of the violet light will be greater than that of the red light.

(3) Triangular prisms disperse white light while the transparent cuboid slabs don't.

3 **What are the factors on which the following quantities depend?**

(1) The minimum angle of deviation in a triangular prism.

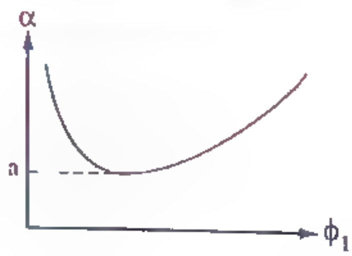
(2) The angle of deviation in the thin prism.

(3) The angular dispersion of light in a thin prism.

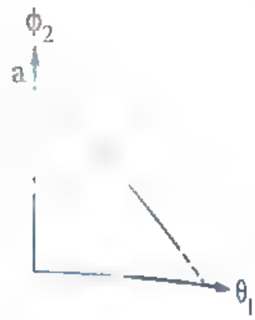
(4) The dispersive power ($\omega_\alpha$) of a thin prism.

4 **What is the quantity that point (a) represents in each of the following graphs?**

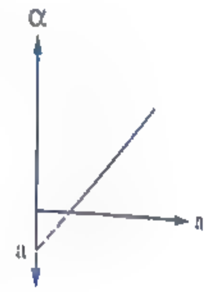
(a) The relation between the angle of deviation ($\alpha$) of a light ray in a triangular prism and the first angle of incidence ($\phi_1$) for the light ray on one of the faces of the prism.



(b) The relation between the second angle of incidence ($\phi_2$) for a ray falling on a prism and the first angle of refraction ($\theta_1$).




(c) The relation between the angle of deviation ($\alpha$) in different thin prisms that have equal apex angles and the refractive indices (n) for them.




5 A monochromatic light ray falls on one of the faces of triangular prism and emerges tangent to the opposite face, **what happens to** the angle of deviation ($\alpha$) of the light ray if the ray is rotated gradually towards the base of the prism such that the first angle of incidence increases? **Show that** with a graph representing the relation between the deviation angle and the first angle of incidence.

## New Types of questions

Understand Apply Higher Order Thinking Skills

**First : Choose two correct answers in each of the following :**

**1** A light ray is incident with an angle of 45° on one of the faces of a triangular prism whose material refractive index is $\sqrt{2}$, if the ray emerges from the opposite face with an angle of 45°, so ........

a) the apex angle of the prism is 30°

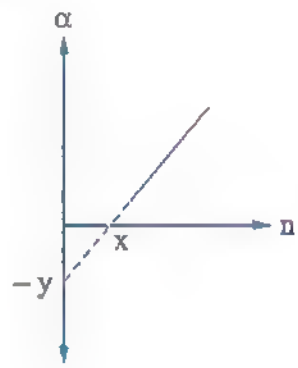
b) the apex angle of the prism is 45°

c) the apex angle of the prism is 60°

d) the angle of deviation of the ray equals 30°

e) the angle of deviation of the ray equals 45°

**2** The opposite graph represents the variation of the angle of deviation ($\alpha$) versus the material refractive index (n) of a thin prism for different wavelengths, so ........




a) the slope of the graph line equals the apex angle of the prism

b) the quotient of $\frac{x}{y}$ equals the apex angle of the prism

c) the quotient of $\frac{y}{x}$ equals the apex angle of the prism

d) the value of x represents the minimum angle of deviation

e) the value of y represents the minimum angle of deviation

**Second: Put in front of each of the following sentences the light color that makes the magnitude of the physical quantity greater:**

**Red light** **Blue light**

(1) The wavelength of light (........................)

(2) The frequency of light (........................)

(3) The refractive index of a prism for light (........................)

(4) The angle of deviation of light rays through a prism when they are incident with the same angle of incidence on the prism (........................)

(5) The critical angle of the prism material when light passes through it (........................)

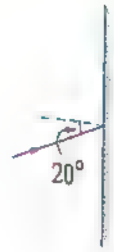
(6) The angle of emergence of light rays from a prism when they are incident with the same angle of incidence on the prism (........................)

Test on Chapter 2

# Light

## First Choose the correct answer

1. The opposite figure shows a light ray falling on a plane mirror at an angle of incidence 20°. If the mirror is rotated in clockwise direction by an angle of 20° about an axis perpendicular to the page at the point of incidence, the angle of reflection .......... .



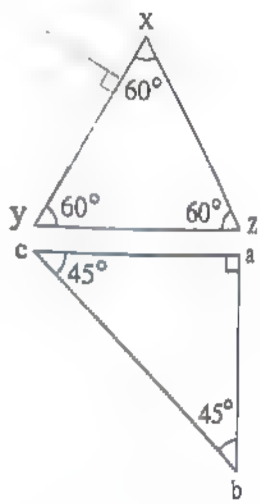

ⓐ increases by 20°

ⓑ decreases by 10°

ⓒ increases by 40°

ⓓ decreases by 40°

2. The opposite figure shows two different prisms which are made of the same material of refractive index 1.5. If a light ray falls perpendicular on face xy, it will emerge perpendicularly from face .......... .



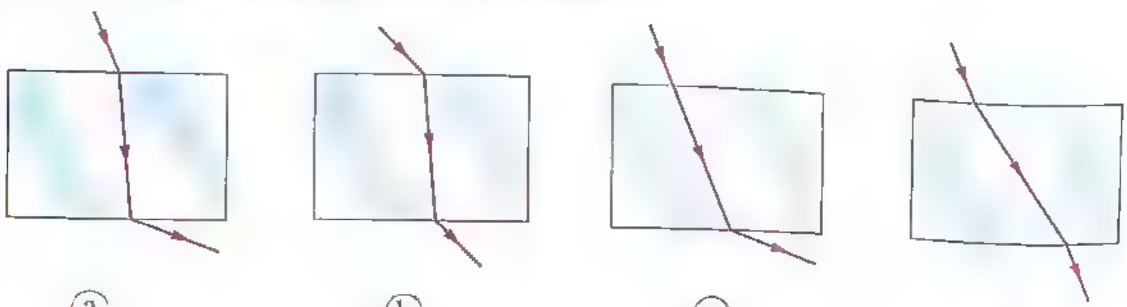

ⓐ xz

ⓑ ac

ⓒ bc

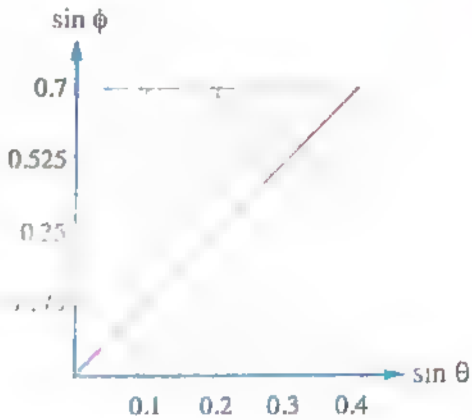
ⓓ ab

3. Which of the following figures represents correctly the path of a light ray that is incident from air and passes through a cuboid glass slab?



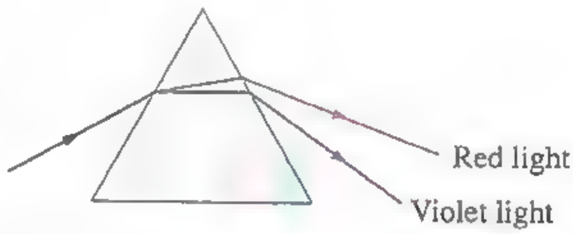
ⓐ ⓑ ⓒ ⓓ

4. The opposite graph depicts the relation between sine of the angle of incidence (sin $\phi$) of a light ray in a transparent medium and sine of the angle of refraction (sin $\theta$) of the ray in another medium when the ray travels between them.
If the wavelength of the light ray in the first medium was 700 nm, the wavelength of the ray in the second medium equals .......... .




ⓐ 550 nm
ⓑ 500 nm
ⓒ 450 nm
ⓓ 400 nm

5. The opposite figure represents the falling of white light on a glass triangular prism to emerge from the prism spread out in a series of colors, what is the name of this phenomenon?




ⓐ Light division
ⓑ Light dispersion
ⓒ Light reflection
ⓓ Light diffraction

6. In Young's double-slit experiment, if the distance between the centers of the fourth dark fringe and the central fringe is x, then the distance between the centers of central fringe and the first bright fringe equals .......... .

ⓐ $\frac{x}{4.5}$  ⓑ $\frac{x}{4}$  ⓒ $\frac{x}{3.5}$  ⓓ $\frac{x}{3}$

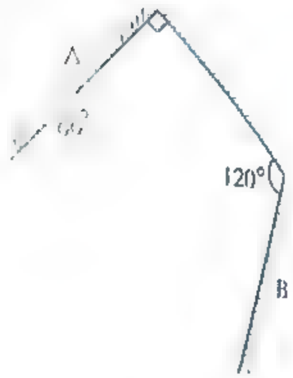
7. A light ray falls in air at an angle of incidence 0° on one of the faces of a triangular prism whose apex angle is 45°. If the ray emerges tangentially from the opposite face, then the speed of light in the prism equals .......... . ($c = 3 \times 10^8$ m/s)

ⓐ $1.96 \times 10^8$ m/s
ⓑ $2.08 \times 10^8$ m/s
ⓒ $2.12 \times 10^8$ m/s
ⓓ $2.41 \times 10^8$ m/s

8. A thin prism has an apex angle that equals double the angle of deviation of a light ray that passes through the prism, so the refractive index of the prism equals .......... .

ⓐ $\sqrt{2}$  ⓑ 1.5  ⓒ $\frac{\sqrt{2}}{2}$  ⓓ 1.75

9. A light ray falls on mirror A as shown in the opposite figure, then its angle of incidence on mirror B equals ......... .




ⓐ 0°
ⓑ 30°
ⓒ 45°
ⓓ 60°

10. A light ray is incident on one of the faces of an equilateral triangular prism getting refracted parallel to the base and emerging with an angle 60°, so the first angle of incidence ($\phi_1$) of the ray equals ......... .

ⓐ 30° ⓑ 45° ⓒ 60° ⓓ 90°

## Second Answer the following questions

11. **Why** is the refractive index of any transparent medium always greater than one?

..........................................................................................................
..........................................................................................................
..........................................................................................................

12. In which phenomenon; refraction or diffraction, **does** the wavelength of the used light remain unchanged? **And why**?

..........................................................................................................
..........................................................................................................
..........................................................................................................

13. When putting a blue light source in the center of a glass cube which was surrounded by white screens facing its lateral faces, a circular light spot appeared on each of the screens, **explain what happened.**

..........................................................................................................
..........................................................................................................
..........................................................................................................
..........................................................................................................
..........................................................................................................

14. A thin prism on which a white light ray is incident with an angle $\phi$ has a dispersive power that equals $\omega_\alpha$, **what happens to** the dispersive power of the prism when increasing the angle of incidence of the light ray? **Explain your answer.**

..........................................................................................................................

..........................................................................................................................

..........................................................................................................................

..........................................................................................................................

..........................................................................................................................

15. A student carries out Young's double-slit experiment by using a monochromatic red light, so an interference pattern appears on the screen with a certain dimensions. **How** can the student get the same interference pattern using the same double-slit but with a monochromatic blue light?

..........................................................................................................................

..........................................................................................................................

..........................................................................................................................

..........................................................................................................................

..........................................................................................................................

16. If you have two different transparent materials A and B and you want to make a double layer optical fiber. **Which** of the two materials will be used for the core and **which of them** for the external layer? **Explain your answer.**
(Knowing that: the refractive index of B is greater than that of A)

..........................................................................................................................

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17. A light ray fell with a small angle of incidence on one of the faces of an equilateral triangular prism and emerged from the opposite face with a certain angle of deviation, **what would happen** to the angle of deviation if the prism was rotated slowly in such away that the incident ray gets closer to the base of the prism?

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# Accumulative Test on Chapters 1 &

## First Choose the correct answer

**1** If the ratio between the frequency of the sound of the voices of a man to that of a girl is $\frac{7}{9}$, the ratio between the speeds of their sounds respectively in air equals .......... .

ⓐ $\frac{7}{9}$

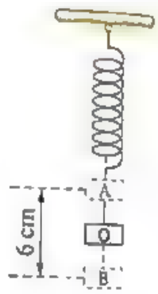
ⓑ $\frac{9}{7}$

ⓒ $\frac{9}{9}$

ⓓ $\frac{7}{1}$

---

**2** The opposite figure shows a load vibrating with an average speed of 4 cm/s, so the frequency of the vibration equals .......... .




ⓐ 6 Hz

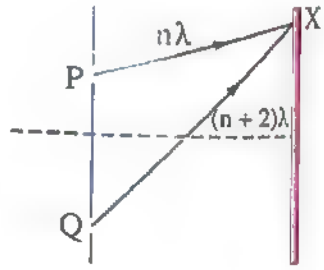
ⓑ 3 Hz

ⓒ $\frac{1}{3}$ Hz

ⓓ $\frac{2}{3}$ Hz

---

**3** The figure shows a double-slit experiment where P and Q are the slits. If the path lengths PX and QX are $n\lambda$ and $(n + 2)\lambda$ respectively, where n is an integer number, $\lambda$ is the wavelength and the order of the central fringe is zero, what is formed at X?




ⓐ First bright fringe.

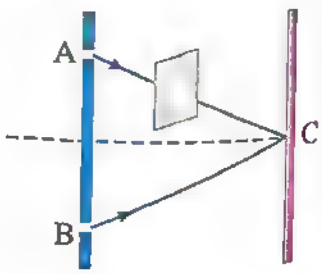
ⓑ First dark fringe.

ⓒ Second bright fringe.

ⓓ Second dark fringe.

---

**4** In Young's experiment, a monochromatic light is used to illuminate the two slits A and B. Interference fringes are observed on a screen placed in front of the slits. Now if a thin glass plate is placed vertically in the path of the beam coming from slit A, what would happen to the fringes?




ⓐ The fringes disappear.

ⓑ Their width increases.

ⓒ Their width decreases.

ⓓ Their pattern shifts.

**5** If the critical angle from a medium to vacuum is 30°, the speed of light in the medium is .......... . (Where: $c = 3 \times 10^8$ m/s)

ⓐ $3 \times 10^8$ m/s
ⓑ $1.5 \times 10^8$ m/s
ⓒ $6 \times 10^8$ m/s
ⓓ [illegible]

**6** In a Young's double-slit experiment, the fringe width that is obtained when conducting the experiment in air equals 0.4 mm. If the whole apparatus is immersed in water of refractive index $\frac{4}{3}$ without disturbing the geometrical arrangement of the apparatus, the new fringe width will be .......... .

ⓐ 0.3 mm
ⓑ 0.4 mm
ⓒ 0.53 mm
ⓓ 450 microns

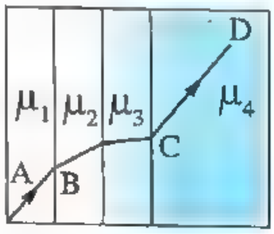
**7** The frequency of a tuning fork is 384 vibrations per second and the speed of sound in air is 352 m/s. How far the sound has travelled as the fork completes 36 vibrations?

ⓐ 3 m
ⓑ 13 m
ⓒ 23 m
ⓓ 33 m

**8** A light ray falls on one of the faces of a thin prism of an apex angle 9°, refractive index for the blue light 1.664 and refractive index for the red light 1.644, then the dispersive power for this prism equals .......... .

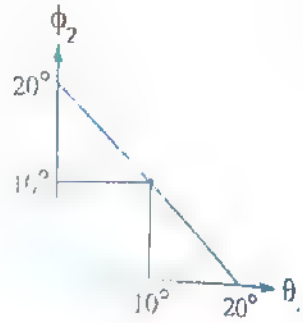
ⓐ 0.05
ⓑ 0.04
ⓒ 0.03
ⓓ 0.02

**9** A ray of light passes through four transparent media with refractive indices $\mu_1$, $\mu_2$, $\mu_3$ and $\mu_4$ as shown in the figure. The surfaces of all media are parallel. If the emergent ray CD is parallel to the incident ray AB, the correct relation is ..........




ⓐ $\mu_1 = \mu_2$
ⓑ $\mu_2 = \mu_3$
ⓒ $\mu_3 = \mu_4$
ⓓ $\mu_4 = \mu_1$

(10) The opposite graph represents the relation between the second angle of incidence ($\phi_2$) and the first refraction angle ($\theta_1$) when the light ray passes through a triangular prism, If the critical angle of the prism is 41.8°, then the minimum deviation angle of the incident light ray is ........ .




(a) 8.43°
(b) 10.2°
(c) 15.46°
(d) 20.25°

## Second Answer the following questions

(11) A tower clock makes a signal of light with a whistle every 1 hour. A man at 8 km from the tower sets his watch by the light signal of the tower. Another man sets his watch by the sound of the whistle. If the two watches of both men have a time difference 3 seconds, **calculate** the distance between the man who sets his watch by the whistle and the tower **and find which** of their watches is more accurate?

(Knowing that: speed of sound in air = 360 m/s, speed of light in air = $3 \times 10^8$ m/s)

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(12) If the distance between the second crest and the seventh one of a transverse wave is 20 m and the time interval between the first crest and the fifth one when they pass a certain point in the path of the wave motion is 0.1 s, **calculate:**

(a) The wavelength of the wave motion.

(b) The frequency of the source of disturbance.

(c) The wave speed.

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13 A light ray falls on water surface with an angle that equals 45°, **calculate** the angle between the reflected ray and the refracted ray.

(Knowing that: The refractive index of water = 1.33)

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14 Light ray of wavelength $5 \times 10^{-7}$ m falls from air on the plane surface of a glass piece whose refractive index equals 1.5. **Calculate:**

(a) The speed of light in the glass.

(b) The frequency of light ray in the glass.

(Knowing that: The speed of light in air = $3 \times 10^{8}$ m/s)

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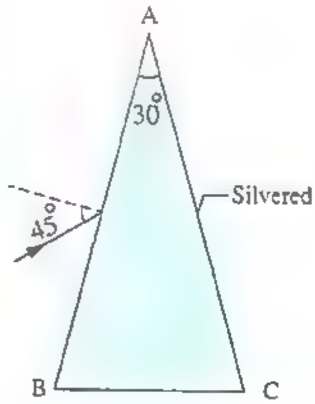
15 A triangular prism ABC of angle 30° has its face AC silvered.

A ray of light is incident at an angle of 45° at the face AB and reflects back on itself at face AC. **Calculate** the refractive index of the material of the prism.

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16. A thin glass prism of refractive index 1.5 is put in a transparent liquid whose refractive index is 1.2, **calculate** the apex angle of the prism if the ray deviates by an angle of 2 degrees.

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17. In one of the experiments to find the wavelength of a monochromatic light using Young's double slits experiment, the distance between the double slit and the observation screen was 2 m, then the following results for the distance between two successive bright fringes ($\Delta y$) and the reciprocal of the distance between the two slits ($\frac{1}{d}$) were recorded:

| $\Delta y \times 10^{-3}$(m) | 10 | b | 18 | 25 | 30 |
|---|---|---|---|---|---|
| $\frac{1}{d} \times 10^{4}$ ($m^{-1}$) | 0.9 | 1 | a | 2.1 | 2.5 |

(a) **Plot** the relation between ($\Delta y$) on the (y-axis) and ($\frac{1}{d}$) on (x-axis).

(b) **From the graph find:**

1- The value of both (a) and (b).

2- The wavelength of the used monochromatic light.

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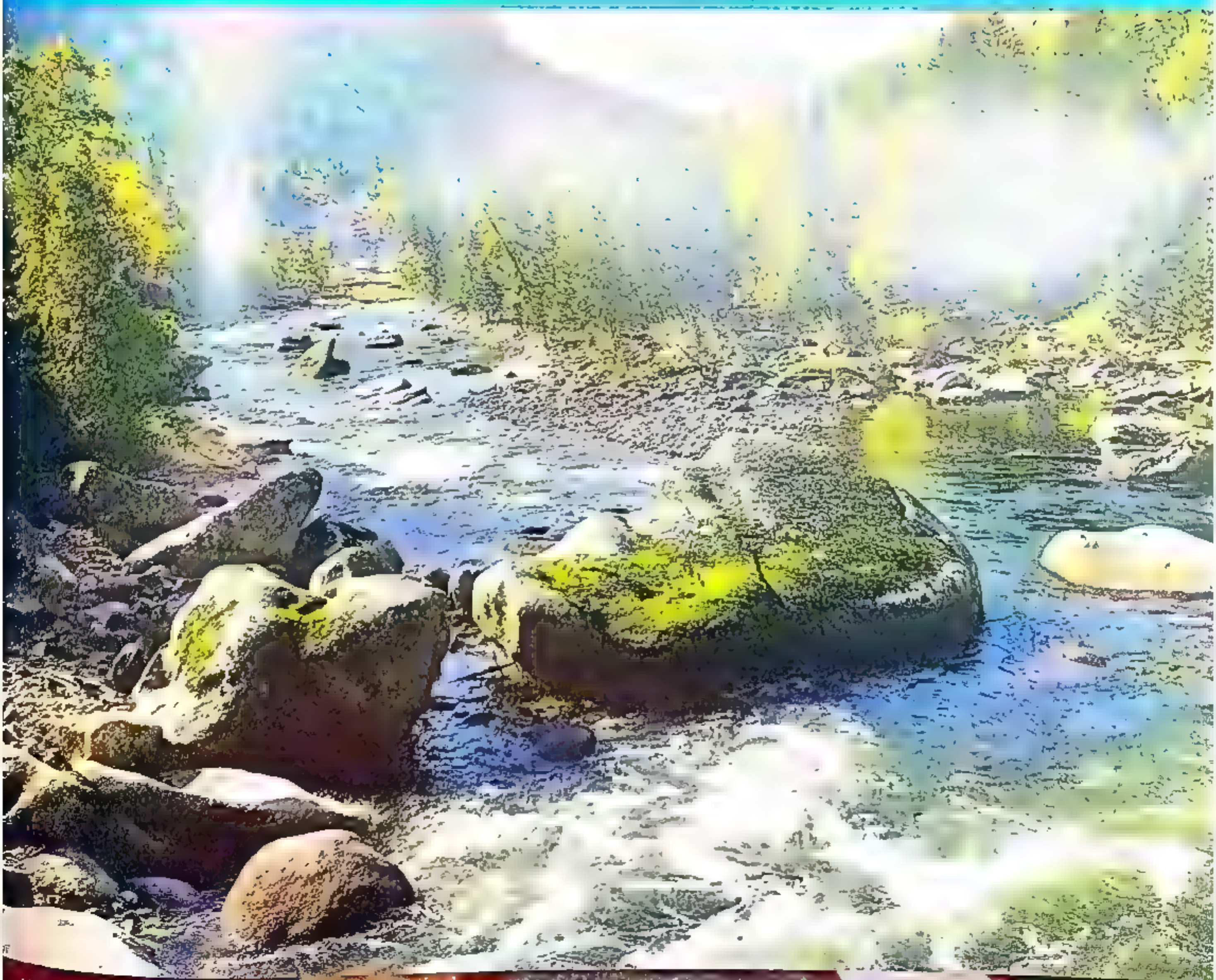
# Unit Two

CHAPTER 4 Hydrodynamics.



CHAPTER

# 4 Hydrodynamics

Lesson 1

Lesson 2 Viscosity

- Test on Chapter 4
- Accumulative test on Chapters 1, 2, 3, 4

## Chapter objectives

By the end of this Chapter, the student will be able to:

- Distinguish between the steady flow and turbulent flow.
- Mention the characteristics of streamlines.
- Mention the conditions of steady flow of a liquid.
- Define the rate of flow.
- Deduce the continuity equation.
- Explain some applications of the continuity equation.
- Carry out some activities to explore the viscosity concept.
- Explain viscosity.
- Know the concept of viscosity coefficient and its measuring unit.
- Explain some applications of viscosity.
- Acquire the skills of solving problems on laws mentioned in this chapter.


Chapter 4

Lesson One

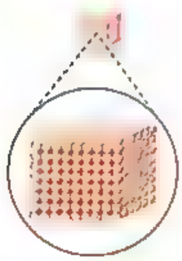
# Fluid Flow

## The states of matter

You have studied in the previous years that matter can be found in one of three states:

**Solid**

Its molecules are **tightly packed (the spaces between them are very small)** and they are locked into their places in a regular pattern, so a solid has definite shape and volume.

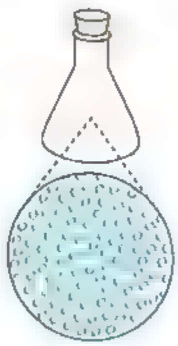


**Examples**

Wood and glass

**Liquid**

Its molecules are **close together** with no regular arrangement and they can move and slide past each other, so a liquid doesn't have a definite shape and it takes the shape of its container, so it is called a fluid.

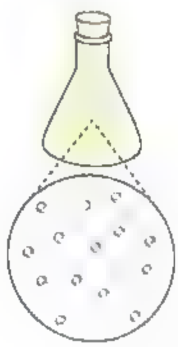


**Examples**

Water and oil

**Gas**

Its molecules are separated by **relatively large spaces** with no regular arrangement and they move freely at high speeds, so a gas doesn't have a definite shape but it takes the shape of its container, so it is called a fluid.



**Examples**

Chlorine gas

**➲ From the previous, a fluid can be defined as follows:**

**A fluid:**

It is a material that can flow and has no definite shape, [illegible] liquids and gases.

Fluid

In this chapter, we will study only two of the properties of the moving fluids which are:

**Flow** — **Viscosity**

**And in this lesson, we will study the flow of liquids in some detail.**

## Flow

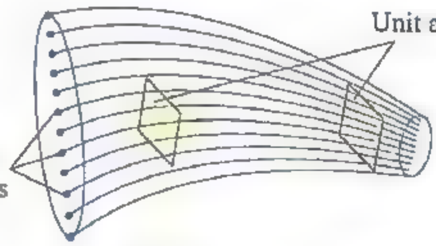
**The flow of liquids are classified into two types:**

1. Steady flow
2. Turbulent flow

### 1 Steady flow

When a liquid moves such that its adjacent layers slide smoothly over each other, we describe this motion as a **laminar flow** or a **streamline (steady) flow**, where every small amount of the liquid follows a continuous imaginary path called **streamline**.

#### Characteristics of streamlines:

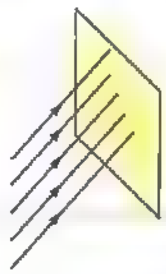



*Streamline flow*

1. They are imaginary lines that do not intersect.
2. The number of streamlines at any cross-section of the tube is constant.
3. The direction of the instantaneous velocity (v) of a small amount of a liquid at a certain point along a streamline is determined by the tangent of that streamline at that point.
4. The flow speed of a liquid at a point is determined by the density of streamlines at that point, so the speed of fluid flow increases by increasing the density of streamlines at that point and decreases by decreasing the density of streamlines.

**Density of streamlines at a point :**

It is estimated by the number of streamlines that pass perpendicularly through a unit area surrounding that point.

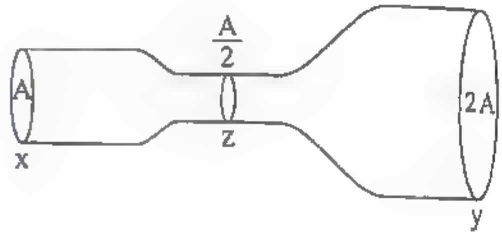


## Conditions of steady flow :

1. The speed of the liquid at one given point along the path of the liquid remains constant and does not change as time passes.
2. The flow is irrotational , *i.e.* there is no vortex motion.
3. No frictional forces exist between the layers of the liquid.
4. The flow rate of the liquid should be constant along its path because the liquid is incompressible and its density does not change with distance or time.
5. The liquid fills the tube completely such that the amount of liquid (volume and mass) that enters the tube at one end equals the amount of liquid that emerges from the other end in the same time interval according to the law of mass conservation.

### Example

*The opposite figure shows a liquid flowing steadily in a tube from one terminal to the other, so the ratio of the numbers of streamlines through the cross-sections x : y : z is ..........*




ⓐ 2 : 1 : 4 ⓑ 1 : 2 : 4

ⓒ 2 : 4 : 1 ⓓ 1 : 1 : 1

### Solution

In the steady flow, the number of streamlines through any cross-section of the tube remains constant where the streamlines don't intersect.

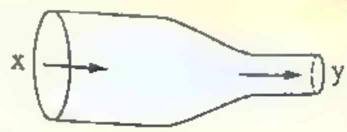
∴ The correct choice is ⓓ.

What if you are asked to determine, at which of the three cross-sections x, y or z, the density of the streamlines is higher, **what** will be your answer?

## 1 Test yourself

Answered

✻ The opposite figure shows a liquid flowing steadily from terminal x to terminal y in a tube, **determine if the following statement is true and explain your answer:**




The speed of the liquid at terminal x = The speed of the liquid at terminal y

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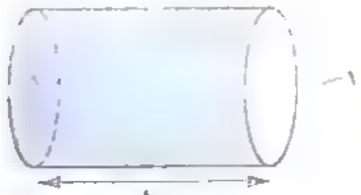
## Flow rate

- Consider a quantity of volume $V_{ol}$ and mass m of a liquid of density ρ flowing through a cross-sectional area of a tube A at velocity v, where it covers a distance Δx in time Δt as in the figure, then:

**Density (ρ) :**
It is the mass of a unit volume of the material. It is measured in $kg/m^3$ and calculated from the relation:

$$\rho = \frac{m}{V_{ol}}$$




| Volume flow rate ($Q_v$) | Mass flow rate ($Q_m$) |
|---|---|

**Concept**

| Volume flow rate ($Q_v$) | Mass flow rate ($Q_m$) |
|---|---|
| The volume of liquid that flows steadily through a definite cross-section of a tube in one second. | The mass of liquid that flows steadily through a definite cross-section of a tube in one second. |

**Deducing the equation**

Volume flow rate:

$$\because V_{ol} = A\Delta x$$

$$\therefore Q_v = \frac{V_{ol}}{\Delta t} = A\frac{\Delta x}{\Delta t}$$

$$\boxed{Q_v = Av}$$

Mass flow rate:

$$\because m = \rho V_{ol} = \rho A \Delta x$$

$$\therefore Q_m = \frac{m}{\Delta t} = \rho A \frac{\Delta x}{\Delta t}$$

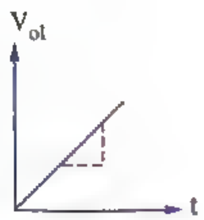
$$\boxed{Q_m = \rho A v}$$

$$\therefore \boxed{Q_m = \rho Q_v}$$

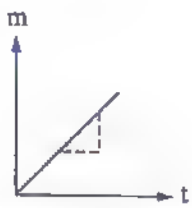
**Measuring unit**

| Volume flow rate ($Q_v$) | Mass flow rate ($Q_m$) |
|---|---|
| $m^3/s$ | kg/s |

**Graphical representation**




$$\text{Slope} = \frac{\Delta V_{ol}}{\Delta t} = Q_v$$

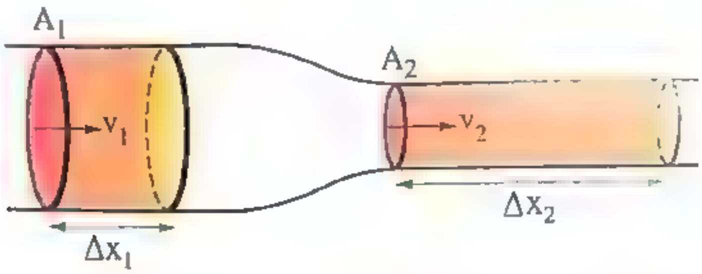



$$\text{Slope} = \frac{\Delta m}{\Delta t} = Q_m$$

**From the previous, we conclude that:**
When the liquid flows steadily across a tube, the flow rate (volume or mass) will be **constant** at any cross-section of the tube.

## Deducing the continuity equation (the relation between the liquid flow speed and the cross-sectional area of the tube) :

- Assume two different cross-sections of a tube that contains a liquid of density ρ, flowing steadily as in the following figure:




| In the first cross-section ($A_1$) | | In the second cross-section ($A_2$) |
|---|---|---|
| | **The volume flow rate** | |
| $Q_v = A_1 v_1$ | | $Q_v = A_2 v_2$ |
| | **The mass flow rate** | |
| $Q_m = \rho A_1 v_1$ | | $Q_m = \rho A_2 v_2$ |

∵ The liquid flows steadily.

∴ The flow rate (volume or mass) is constant at any cross-section of the tube.

∴ $\rho A_1 v_1 = \rho A_2 v_2$ ∴ $A_1 v_1 = A_2 v_2$

∴ $\boxed{\frac{v_1}{v_2} = \frac{A_2}{A_1}}$ , this relation is called the **continuity equation**.

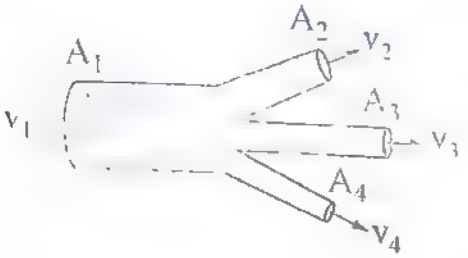
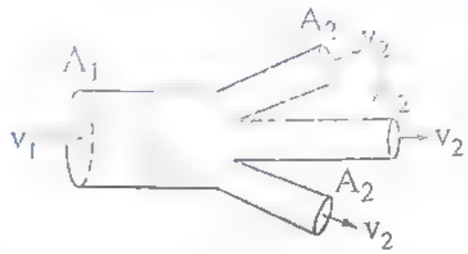
∵ $A = \pi r^2$ , where r is the radius of the tube cross-section.

∴ $\boxed{\frac{v_1}{v_2} = \frac{r_2^2}{r_1^2} = \frac{d_2^2}{d_1^2}}$ , where d is the diameter of the tube cross-section.

### From the previous, we can conclude that :

The speed of a liquid that is flowing steadily in a tube at any point is inversely proportional to the cross-sectional area of the tube (as well as the square of the radius of the tube and also the square of its diameter) at that point.

☆ **When the liquid flows steadily in a tube that branches into a number of branches of:**

| Different cross-sectional areas | The same cross-sectional area |
|---|---|
|   |   |

**then**

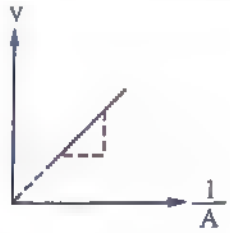
| | |
|---|---|
| $A_1v_1 = A_2v_2 + A_3v_3 + A_4v_4$ | $A_1v_1 = nA_2v_2$<br>(where n is the number of branches) |
| $r_1^2 v_1 = r_2^2 v_2 + r_3^2 v_3 + r_4^2 v_4$ | $r_1^2 v_1 = nr_2^2 v_2$ |
| $d_1^2 v_1 = d_2^2 v_2 + d_3^2 v_3 + d_4^2 v_4$ | $d_1^2 v_1 = nd_2^2 v_2$ |

## Notes :

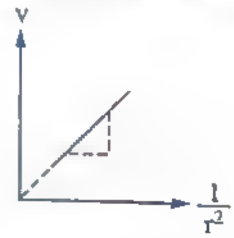
(1) When a liquid flows steadily in a tube of non-uniform cross-sectional area, we can represent the graphical relation between:

| **Velocity of the liquid (v) and reciprocal of the cross-sectional area $\left(\frac{1}{A}\right)$** | Velocity of the liquid (v) and reciprocal of square of the cross-sectional radius $\left(\frac{1}{r^2}\right)$ |
|---|---|

**As follows**




$$\text{Slope} = \frac{\Delta v}{\Delta\left(\frac{1}{A}\right)} = Q_v$$




$$\text{Slope} = \frac{\Delta v}{\Delta\left(\frac{1}{r^2}\right)} = \frac{Q_v}{\pi}$$

(2) When opening multiple taps together to fill a container with a liquid such that the flow rate of the liquid from each tap is $(Q_v)_1$, $(Q_v)_2$, $(Q_v)_3$, then the total flow rate $(Q_v)$ of filling the container is calculated from the relation:

$$Q_v = (Q_v)_1 + (Q_v)_2 + (Q_v)_3$$

(3) When a liquid flows steadily in a tube, then at any cross-section of the tube;

$Q_v$ (Volume flow rate) $= Av = \pi r^2 v = \frac{Q_m}{\rho} = \frac{V_{ol}}{t} = \frac{m}{\rho t}$

(4) When a liquid flows in a tube with two different cross-sectional area,

To compare the liquid flow at both cross-sections:

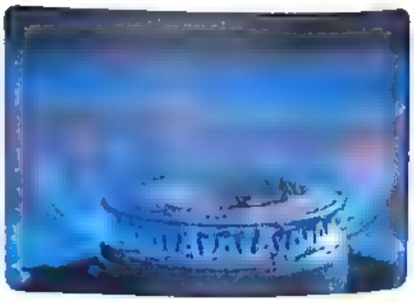
- $(Q_v)_1 = (Q_v)_2$
- $(Q_m)_1 = (Q_m)_2$
- $A_1 v_1 = A_2 v_2$
- $r_1^2 v_1 = r_2^2 v_2$
- $d_1^2 v_1 = d_2^2 v_2$

## Life applications of continuity equation :

### 1. The flow of blood in blood capillaries:

The speed of blood flow is faster in the main artery than that in blood capillaries because the total cross-sectional areas of the blood capillaries is greater than the cross-sectional area of the main artery, so the speed of blood flow decreases in the blood capillaries where $\left(v \propto \frac{1}{A}\right)$. Blood flow is slower in the blood capillaries to allow gases exchange (oxygen and carbon dioxide) with the tissues and supply them with nutrients.

### 2. The design of gas burners holes:



The holes of the gas burners in the stoves are designed to be small so that the gas rushes out with high speed $\left(v \propto \frac{1}{A}\right)$ to control the direction of flames.

### 3. The design of the nozzle of the fire hose:

The fire hose is designed to end with a narrow nozzle so that water rushes out with high speed to reach far places quicker.

## Example 1

*Water flows from a water tap in the rate of 0.5 kg/s, so the time required to fill a container of volume 2 $m^3$ using this tap is .......... .*
*(Where: $\rho_{water} = 1000\ kg/m^3$)*

ⓐ $10^3$ s  ⓑ $4 \times 10^3$ s  ⓒ $10^4$ s  ⓓ $4 \times 10^4$ s

### Solution

| $Q_m = 0.5$ kg/s | $V_{ol} = 2\ m^3$ | $\rho_{water} = 1000\ kg/m^3$ | $t = ?$ |
|---|---|---|---|

$$V_{ol} = Q_V\, t$$

$$t = \frac{V_{ol}}{Q_V} = \frac{V_{ol}\,\rho}{Q_m}$$

$$= \frac{2 \times 1000}{0.5}$$

$$= 4 \times 10^3\ s$$

∴ **The correct choice is ⓑ.**

**What if** the water flow rate from the tap is 0.5 liter/s, will this change the time required to fill the container?

## Example 2

*The opposite figure shows a water container of volume $V_{ol}$ which can be filled using two water taps x and y such that if only tap x is used, the container takes 15 minutes to be filled but if only tap y is used, the container takes 30 minutes to be filled, then the time required to fill the container by using the two taps x and y together is .......... .*


ⓐ 5 minutes  ⓑ 10 minutes
ⓒ 15 minutes  ⓓ 45 minutes

### Solution

| $t_x = 15$ minutes | $t_y = 30$ minutes | $t = ?$ |
|---|---|---|

$$Q_v = (Q_v)_x + (Q_v)_y$$

$$\frac{V_{ol}}{t} = \frac{V_{ol}}{t_x} + \frac{V_{ol}}{t_y}$$

∵ The volume ($V_{ol}$) of the container is fixed.

$$\therefore \frac{1}{t} = \frac{1}{t_x} + \frac{1}{t_y} = \frac{1}{15} + \frac{1}{30} = \frac{1}{10}$$

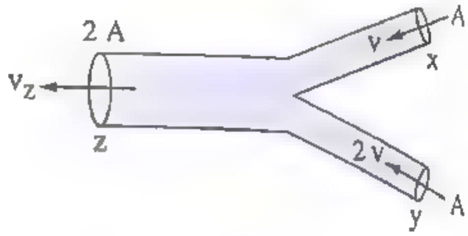
$\therefore t = 10$ minutes

$\therefore$ **The correct choice is ⓑ.**

**What if** a third tap z is used which individually fills the containe[illegible], so what is the required time to fill the container using the three taps tog[illegible]?

## Example 3

*A liquid flows steadily in a tube as in the opposite figure. If the cross-sectional areas of x, y, z are A, A, 2 A respectively and the liquid speeds at the cross-sections x, y are v, 2 v respectively, then the liquid speed at z equals ........... .*




ⓐ 2 v  ⓑ $\frac{2}{3}$ v  ⓒ $\frac{3}{2}$ v  ⓓ v

### Solution

$A_x = A$ | $v_x = v$ | $A_y = A$ | $v_y = 2\,v$ | $A_z = 2\,A$ | $v_z = ?$

$$A_z v_z = A_x v_x + A_y v_y$$

$$2\,A v_z = A\,v + 2\,Av$$

$$2\,v_z = 3\,v$$

$$v_z = \frac{3}{2}\,v$$

$\therefore$ **The correct choice is ⓒ.**

## Example 4

*A water pipe of diameter 2 cm in which water flows with a speed of 0.1 m/s. The pipe enters a house, where its diameter becomes 1 cm. Given that the density of water is 1000 kg/m³, calculate:*

*(a)* The speed of water in the pipe inside the house.

*(b)* The volume and the mass of the water that flows every minute through any cross-section of the pipe.

### Solution

$d_1 = 2$ cm | $v_1 = 0.1$ m/s | $d_2 = 1$ cm | $t = 60$ s | $\rho = 1000\ kg/m^3$

$v_2 = ?$ | $V_{ol} = ?$ | $m = ?$

*(a)* $d_1^2 \, v_1 = d_2^2 \, v_2$

$(2)^2 \times 0.1 = (1)^2 \times v_2$

$v_2 = 0.4 \text{ m/s}$

*(b)* $V_{ol} = Q_v \, t = A_1 v_1 t = \pi r_1^2 v_1 t$

$= \frac{22}{7} \times \left(\frac{1}{2} \times 2 \times 10^{-2}\right)^2 \times 0.1 \times 60$

$= 1.89 \times 10^{-3} \text{ m}^3$

$m = \rho V_{ol} = 1000 \times 1.89 \times 10^{-3} = 1.89 \text{ kg}$

## Example 5

*The average speed of blood in one of the arteries of an adult person is 0.33 m/s. If the radius of that artery is 0.7 cm and it distributes blood to 30 smaller arteries each of radius 0.35 cm, then the average blood speed inside these small arteries equals .......... .*

ⓐ 0.011 m/s ⓑ 0.022 m/s ⓒ 0.033 m/s ⓓ 0.044 m/s

### Solution

$v_1 = 0.33$ m/s | $r_1 = 0.7$ cm | $n = 30$ | $r_2 = 0.35$ cm | $v_2 = ?$

$A_1 v_1 = A_2 \, v_2$

$\pi r_1^2 v_1 = n \pi r_2^2 v_2$

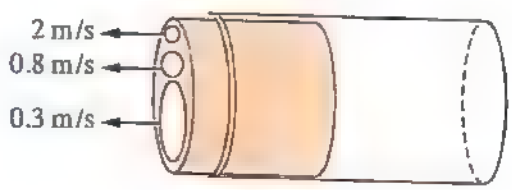
$(0.7)^2 \times 0.33 = 30 \times (0.35)^2 \times v_2$

$v_2 = 0.044 \text{ m/s}$

$\therefore$ **The correct choice is ⓓ.**

## Example 6

*A tube of radius 5 cm ends with a stopper having 3 holes of radii 0.5 cm, 1 cm and 2.5 cm. If the speeds of water when emerging out from the three holes are 2 m/s, 0.8 m/s and 0.3 m/s respectively as in the figure, calculate:*




*(a)* The speed of water in the main tube.

*(b)* The volume of the flowing water in the main tube during half a minute.

**Solution**

| $r_1 = 5$ cm | $r_2 = 0.5$ cm | $r_3 = 1$ cm | $r_4 = 2.5$ cm | $v_2 = 2$ m/s |
|---|---|---|---|---|
| $v_3 = 0.8$ m/s | $v_4 = 0.3$ m/s | $t = 30$ s | $v_1 = ?$ | $V_{ol} = ?$ |

*(a)* $\because A_1 v_1 = A_2 v_2 + A_3 v_3 + A_4 v_4$

$\therefore r_1^2\, v_1 = r_2^2\, v_2 + r_3^2\, v_3 + r_4^2\, v_4$

$(5)^2 \times v_1 = (0.5)^2 \times 2 + (1)^2 \times 0.8 + (2.5)^2 \times 0.3$

$v_1 = 0.127$ m/s

*(b)* $V_{ol} = (Q_v)_1\, t = A_1 v_1 t = \pi r_1^2 v_1 t$

$= \frac{22}{7} \times (5 \times 10^{-2})^2 \times 0.127 \times 30 = 0.03 \text{ m}^3$

## 2 Test yourself

Answers

**1** ✻ Water flows inside a tube of radius 2 cm with a speed of 1 m/s. **Calculate** each of the volume flow rate and the mass flow rate for the water in the tube.

(Given that : Water density = 1000 kg/m$^3$)

.............................................................................................................................................

.............................................................................................................................................

.............................................................................................................................................

.............................................................................................................................................

**2** **Choose the correct answer:**

(1) Water flows steadily inside a horizontal tube with a certain speed. If the tube diameter decreases to the quarter of its initial value, then the flow speed of water in the narrow part .......... .

ⓐ becomes quarter its original value

ⓑ decreases to $\frac{1}{16}$ of its original value

ⓒ becomes four times its original value

ⓓ increases to 16 times its original value

(2) A liquid flows steadily in a tube of radius r with a speed v. The tube branches into five smaller tubes each of radius 0.2 r, then the liquid speed in any of the branches equals .......... .

ⓐ 0.2 v ⓑ v ⓒ 2 v ⓓ 5 v

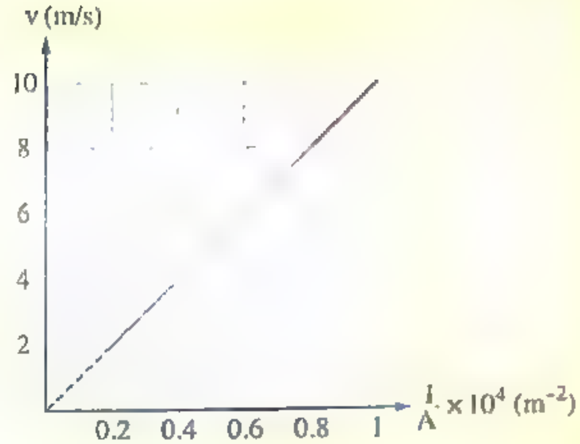
(3) The opposite graph represents the relation between the flow speed (v) of a liquid at a certain point inside a tube and the reciprocal of the cross-sectional area $\left(\frac{1}{A}\right)$ of the tube at that point, then the volume flow rate of the liquid equals .......... .

ⓐ $10^{-4}\ m^3/s$

ⓑ $10^{-3}\ m^3/s$

ⓒ $1\ m^3/s$

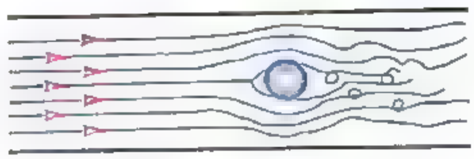
ⓓ $10\ m^3/s$




## 2 Turbulent flow

⊙ The flow of a fluid becomes turbulent which is characterized by the presence of small eddy currents forming vortices as in the figure when:

- The speed of the fluid exceeds a certain limit.
- A gas transfers from small space to a wider space or from high pressure to low pressure.



*Eddy currents*

*Turbulent flow of the smoke*

Chapter 4

Questions on Lesson One

# Fluid Flow

To watch videos of how to solve questions use the App

معاك

MoaakApp

The questions signed by ✳ are answered in detail.

Understand  Apply  Higher Order Skills

Interactive test

## First Multiple choice questions

1. In steady flow of liquids, the ratio between the number of streamlines passing the wide part of a tube to that in the narrow part of the same tube is ..........

   (a) greater than one (b) less than one (c) equal to one (d) indeterminable

2. In steady flow, when the cross-sectional area of the tube decreases, the density of streamlines ..........

   (a) increases
   (b) decreases but doesn't reach zero
   (c) vanishes
   (d) remains unchanged

3. The continuity equation of liquid flow can be deduced from the law of conservation of ..........

   (a) mass (b) energy (c) momentum (d) density

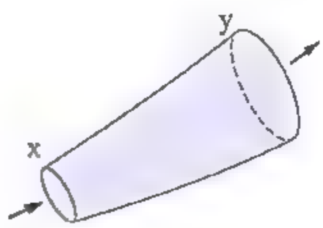
4. The number of streamlines of a liquid which passes perpendicularly through a unit area surrounding a certain point indicates ..........

   (a) the liquid speed at that point
   (b) the volume flow rate
   (c) the mass flow rate
   (d) the liquid density

5. If the cross-sectional area of a tube in which a liquid flows steadily gets increased to the double, then the volume flow rate ..........

   (a) increases to the double
   (b) decreases to its half
   (c) remains constant
   (d) decreases to its quarter

6. In the opposite figure, a liquid flows steadily in a tube, so the physical quantity which is greater at cross-section x than at cross-section y is ..........




   (a) the liquid speed
   (b) the volume of the flowing liquid in unit time
   (c) the mass of the flowing liquid in unit time
   (d) the number of the streamlines through the cross-section

7. The ratio between the mass flow rate and the volume flow rate for a liquid that flows steadily equals ..........

(a) the cross-section of the tube
(b) the time of liquid flow
(c) the speed of liquid flow
(d) the liquid density

8. * A liquid of d[illegible] 1000 kg/m³ [illegible]ws steadily [illegible] 0.5 m² with a flow rate of 10 kg/s, then the flow [illegible] equal to ..........

(a) 200 m/s
(b) 50 m/s
(c) 0.02 m/s
(d) 0.05 m/s

9. * Water flows steadily in a tube of diameter 2 cm at a speed of 5 m/s. Thus;

(i) The volume of water which is flowing through the cross-section of the tube in one minute equals .......... (Where: $\pi = 3.14$)

(a) 9.42 m³
(b) 0.19 m³
(c) 0.0942 m³
(d) 0.001 m³

(ii) The time required to fill a tank of volume 20 m³ by using the flowing water from the tube is ..........

(a) 127.38 minutes
(b) 212.31 minutes
(c) 3.54 minutes
(d) 2.123 minutes

10. * A water pipe has cross-sectional area 4 cm² at the ground floor and 2 cm² at the upper floor. If water is flowing steadily inside the pipe such that its speed at the ground floor was 2 m/s, then: (Given that : Water density = 1000 kg/m³)

(i) The flow speed at the upper floor is ..........

(a) 1 m/s
(b) 2 m/s
(c) 3 m/s
(d) 4 m/s

(ii) The volume flow rate of water at the ground floor equals ..........

(a) $4 \times 10^{-4}$ m³/s
(b) $6 \times 10^{-4}$ m³/s
(c) $8 \times 10^{-4}$ m³/s
(d) $12 \times 10^{-4}$ m³/s

(iii) The mass flow rate of water at the upper floor equals ..........

(a) 1.2 kg/s
(b) 0.8 kg/s
(c) 0.6 kg/s
(d) 0.4 kg/s

11. Water is rushing through a pump opening of cross-sectional area 5 cm² at a speed of 12 m/s. The mass of water coming out from the pump within 30 minutes is ..........
(Given that: Density of water = 1000 kg/m³)

(a) $18.2 \times 10^3$ kg
(b) $15.1 \times 10^3$ kg
(c) $10.8 \times 10^3$ kg
(d) $8.6 \times 10^3$ kg

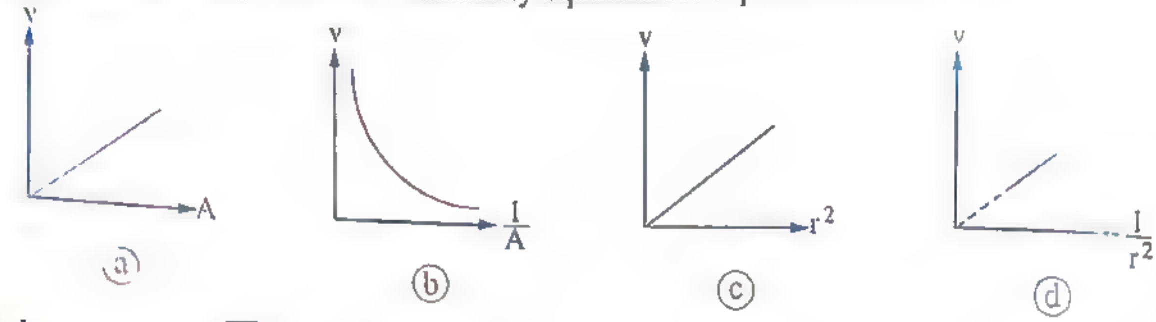
12. * Water flows through a hose of diameter 1.2 cm at a speed of 3 m/s. If the speed of the water that comes out of the nozzle is 27 m/s, then the diameter of the nozzle of the hose equals ..........

(a) 0.2 cm
(b) 0.4 cm
(c) 0.6 cm
(d) 0.8 cm

**13** Water flows steadily through a tube XY such that its speed and its mass flow rate at cross-section X are v, $Q_m$ respectively. If the water speed at cross section Y is $\frac{v}{2}$, then its mass flow rate is equal to ..........

ⓐ $2\,Q_m$ ⓑ $Q_m$ ⓒ $\frac{Q_m}{2}$ ⓓ $\frac{Q_m}{4}$

**14** The graph that represents the continuity equation for liquids flow is ..




**15** ✻ A liquid flows steadily in a tube of radius r at a speed of 4 m/s if the radius of the tube increases to reach 2 r at its end, then the emerging speed of the liquid out of the tube equals ..........

ⓐ 1 m/s ⓑ 2 m/s ⓒ 4 m/s ⓓ 8 m/s

**16** ✻ Oil flows in a tube x at a rate of 6 liters/minute and gets out from another tube y which is connected to the first tube x at a speed of 4 m/s, then the cross-sectional area of the second tube y equals ..........

ⓐ $1.5 \times 10^{-3}\ m^2$ ⓑ $1.5\ m^2$ ⓒ $2.5 \times 10^{-5}\ m^2$ ⓓ $0.025\ m^2$

**17** ✻ Water flows steadily in a tube of cross-sectional area $10^{-3}\ m^2$, if the volume of water which is coming out from the tube within 30 minutes is $18\ m^3$, then ..........

| | Volume flow rate ($m^3/s$) | Speed of water flow (m/s) |
|---|---|---|
| ⓐ | 0.01 | 10 |
| ⓑ | 0.01 | 600 |
| ⓒ | 0.6 | 10 |
| ⓓ | 0.6 | 600 |

**18** If the cross-section of a tube has increased to the double in steady flow, then the flow speed ..........

ⓐ gets doubled ⓑ decreases to half its value
ⓒ gets quadrupled ⓓ remains constant

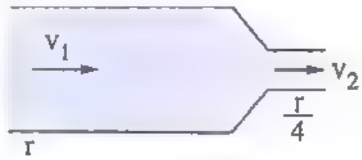
19. If the ratio between the radii of two cross-sections of a tube in steady flow is $\frac{1}{2}$, then the ratio between the speeds of the liquid through them respectively is

ⓐ $\frac{1}{4}$ ⓑ $\frac{1}{2}$ ⓒ $\frac{2}{1}$ ⓓ $\frac{4}{1}$

20. ✻ The speed of steady flow of water in a wide part of a tube is 1.2 m/s while in a narrow part is 6 m/s, then the ratio between the diameter of the wide part and the diameter of the narrow part respectively is ..........

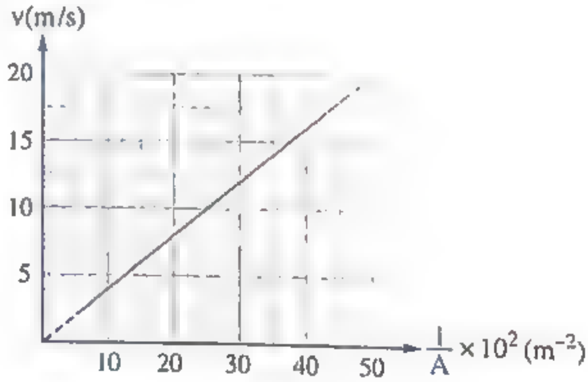
ⓐ $\frac{12}{5}$ ⓑ $\frac{7}{\sqrt{5}}$ ⓒ $\frac{5}{1}$ ⓓ $\frac{\sqrt{5}}{1}$

21. ✻ A liquid flows steadily in a tube that tapers from radius r at one end to radius $\frac{r}{4}$ at the second end as in the opposite figure, then the ratio between the speed of the liquid in the first cross-section of the tube and its speed in the second cross-section of the tube equals ..........




ⓐ $\frac{1}{4}$ ⓑ $\frac{4}{1}$ ⓒ $\frac{1}{16}$ ⓓ $\frac{16}{1}$

22. ✻ The opposite graph illustrates the relation between the liquid flow speed (v) at a point in a tube and the reciprocal of the cross-sectional area of the tube $\left(\frac{1}{A}\right)$ at that point, then:




(i) The volume flow rate equals ..........

ⓐ 40 $m^3/s$ ⓑ 4 $m^3/s$
ⓒ 0.4 $m^3/s$ ⓓ 0.004 $m^3/s$

(ii) The mass of the flowing liquid within 30 minutes if the liquid density is 1000 $kg/m^3$ equals ..........

ⓐ 120 kg ⓑ 1200 kg ⓒ 7200 kg ⓓ $7.2 \times 10^5$ kg

23. ✻ An oil pump pumps 1.2 $m^3$ of oil within 60 s in a cylindrical tank of diameter 4 m and height 3 m. If the oil density is 820 $kg/m^3$, then:

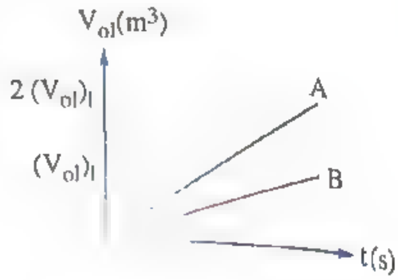
(i) The mass flow rate of the oil from the pump opening equals ..........

ⓐ 0.02 kg/s ⓑ 5.2 kg/s ⓒ 16.4 kg/s ⓓ 18.4 kg/s

(ii) The time required to fill the tank with oil is ..........

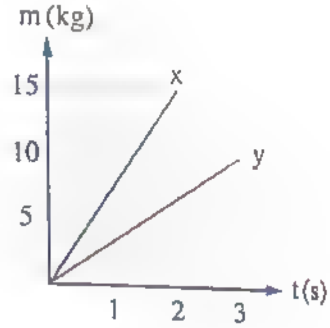
ⓐ 27.21 minutes ⓑ 31.43 minutes ⓒ 42.43 minutes ⓓ 51.54 minutes

24 ✳ Two liquids A, B have densities in a ratio of $\left(\frac{\rho_A}{\rho_B} = \frac{2}{1}\right)$, each flows steadily in a different tube. The opposite graph represents the relation between the liquid volume ($V_{ol}$) that flows through a cross-section of each tube and the flow time (t), then the ratio between the mass flow rates of the two liquids $\left(\frac{(Q_m)_A}{(Q_m)_B}\right)$ equals ..........



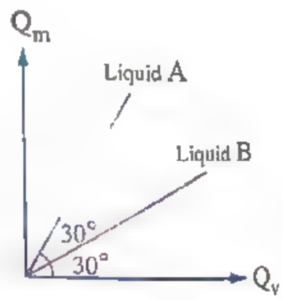

ⓐ $\frac{1}{2}$ ⓑ $\frac{2}{1}$ ⓒ $\frac{1}{4}$ ⓓ $\frac{4}{1}$

25 Two liquids x, y flow steadily in two different tubes of the same cross-sectional area with two different speeds 1.25 v, v respectively. The opposite graph represents the relation between the mass (m) of the liquid which flows through the cross-section of each tube and the flow time (t), then the ratio between the densities of the two liquids $\left(\frac{\rho_x}{\rho_y}\right)$ equals ..........




ⓐ $\frac{9}{5}$ ⓑ $\frac{3}{2}$ ⓒ $\frac{2}{3}$ ⓓ $\frac{5}{9}$

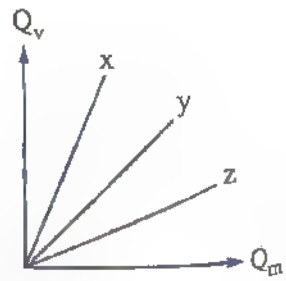
26 Two liquids A, B flow steadily in two similar tubes, where the relation between their mass flow rate ($Q_m$) and their volume flow rate ($Q_v$) is represented graphically as in the opposite figure, then ratio between their densities $\left(\frac{\rho_A}{\rho_B}\right)$ equals ..........




ⓐ $\frac{1}{2}$ ⓑ $\frac{3}{2}$

ⓒ 2 ⓓ 3

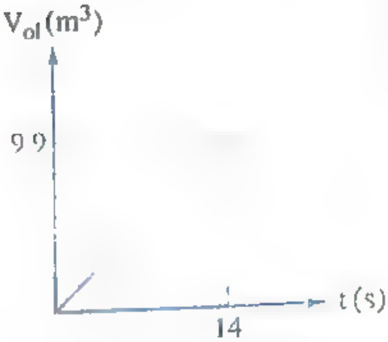
27 The opposite graph represents the relation between the volume flow rate ($Q_v$) and the mass flow rate ($Q_m$) for each of three liquids x, y, z where each flows steadily in a different tube, so ..........




ⓐ $\rho_z < \rho_x < \rho_y$ ⓑ $\rho_z < \rho_y < \rho_x$

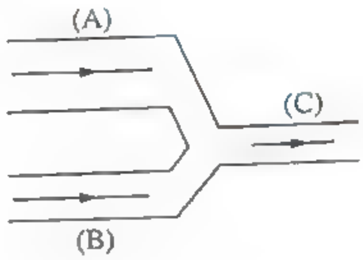
ⓒ $\rho_x < \rho_z < \rho_y$ ⓓ $\rho_x < \rho_y < \rho_z$

28. The opposite graph represents the relation between the volume ($V_{ol}$) of a liquid that flows steadily in a uniform tube and the flow time (t), so if the flow speed of the liquid is 0.9 m/s, then radius of the tube equals



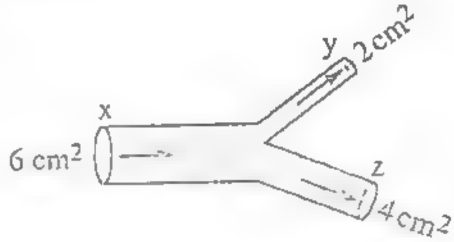

ⓐ 0.3 m ⓑ 0.5 m
ⓒ 0.9 m ⓓ 1.2 m

29. In the opposite figure, the tubes (A) and (B) are different in cross-sectional area and the steady flow rate of the liquid inside each of them is 0.3 $m^3/s$. The two tubes meet to open in the tube (C) as in the figure, then the volume flow rate in the tube (C) is ..........




ⓐ 0.1 $m^3/s$ ⓑ 0.3 $m^3/s$
ⓒ 0.6 $m^3/s$ ⓓ 0.9 $m^3/s$

30. In the opposite figure, the speeds of the steady flow of water at x and z are 8 m/s and 4 m/s respectively, then its speed at y is .......... .




ⓐ 16 m/s ⓑ 12 m/s
ⓒ 8 m/s ⓓ 6 m/s

31. Water flows steadily in a tube of radius 4 cm at an average speed of 0.1 m/s. If the end of the tube is closed with a stopper having 4 openings, each of radius 0.5 cm, then the flow speed from each opening is .......... (Take : $\pi = \frac{22}{7}$)

ⓐ 0.2 m/s ⓑ 0.6 m/s ⓒ 1.6 m/s ⓓ 5 m/s

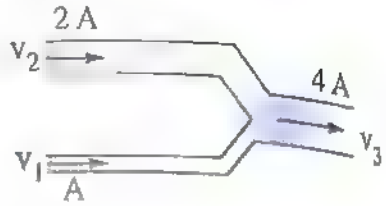
32. A tube of radius r branches into a number of tubes, each of radius 0.04 r. If the flow speed of the liquid in any of these tubes is five times its speed in the main tube, then the number of the small tubes is ..........

ⓐ 5 ⓑ 125 ⓒ 140 ⓓ 150

33. * Blood flows through an artery with an average speed of 0.24 m/s. If the artery branches into 120 smaller arteries each of diameter that is $\frac{1}{4}$ of the big one, then the flow speed of blood in every small artery equals ..........

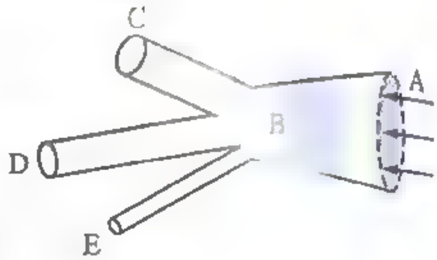
ⓐ $8 \times 10^{-3}$ m/s ⓑ 0.08 m/s ⓒ 0.032 m/s ⓓ 0.3 m/s

34 ✱ The opposite figure shows a steady flow of water in a tube. If $v_1 = 2 v_2 = v$, then $v_3$ equals ..........




ⓐ v ⓑ $\frac{v}{2}$
ⓒ 2 v ⓓ 3 v

35 ✱ The following table shows the data which describes the flow of water in the opposite figure: (Take : $\pi = 3.14$)




| Section | Radius (cm) | Flow speed (m/s) |
|---|---|---|
| A | 30 | 2 |
| B | 20 | $v_B$ |
| C | 15 | 3 |
| D | 10 | $v_D$ |
| E | 5 | 15 |

Then:

(i) The volume flow rate at (A) equals ..........

ⓐ 0.2826 $m^3/s$ ⓑ 0.5652 $m^3/s$
ⓒ 1.884 $m^3/s$ ⓓ 5652 $m^3/s$

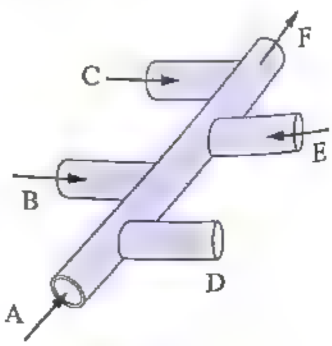
(ii) The flow speed of water at cross-section B equals ..........

ⓐ 1.3 m/s ⓑ 2.5 m/s ⓒ 4.5 m/s ⓓ 5.6 m/s

(iii) The flow speed of water at cross-section D equals ..........

ⓐ 1.56 m/s ⓑ 7.5 m/s ⓒ 10 m/s ⓓ 12.5 m/s

36 ✱ The opposite figure shows a tube that has different branches through which water flows steadily. If the volume flow rates at branches A, B, C, E and F are 6 $cm^3/s$, 3 $cm^3/s$, 5 $cm^3/s$, 4 $cm^3/s$ and 3 $cm^3/s$ respectively, then .......... .



| | Direction of water flow in branch D | Volume flow rate of water at D |
|---|---|---|
| (a) | into | $7\ cm^3/s$ |
| (b) | into | $15\ cm^3/s$ |
| (c) | out of | $7\ cm^3/s$ |
| (d) | out of | $15\ cm^3/s$ |

37 * A water tank takes 10 minutes to be filled using three water taps together, takes 20 minutes when using the first water tap only and an hour when using the second water tap only, then the time required to fill the tank using the third water tap only is ..........

ⓐ 10 minutes ⓑ 20 minutes ⓒ 30 minutes ⓓ 60 minutes

## Second Essay questions

1 The opposite figure shows a liquid that flows steadily in a tube, **determine which of the following ratios is greater than, less than or equal to one:**


(a) The ratio between the streamlines density at cross-section A and the streamlines density at cross-section B.

(b) The ratio between the volume flow rate at cross-section A and the volume flow rate at cross-section B.

(c) The ratio between the mass flow rate at cross-section A and the mass flow rate at cross-section B.

(d) The ratio between the speed of liquid flow at cross-section A and the speed of liquid flow at cross-section B.

2 **Explain the following statements:**

(1) Streamlines in steady flow become crowded at the cross-section of high liquid speeds.

(2) In steady flow, the liquid flow rate is always constant at any cross-section of the tube.

(3) In steady flow, the liquid flow is slow at the wider cross-section of the tube and fast at the smaller cross-section of the tube.

(4) The cross-sectional area of the water column flowing from the nozzle of a hose decreases when it is directed downwards and increases when it is directed upwards.

(5) The openings of the gas stove are made small.

3. In October War, the Egyptian Army used water pumps to rush [illegible] hoses with narrow nozzles to open paths in Bar Lev Line, **why do you think** [illegible] nozzles should be narrow?

4. What are the results of the following (mention the reason [illegible]

(1) Increasing the speed of a steady flowing liquid to exceed a certain limit for [illegible] type of flow?

(2) A main artery is ended by a large number of blood capillaries concerning blood speed?

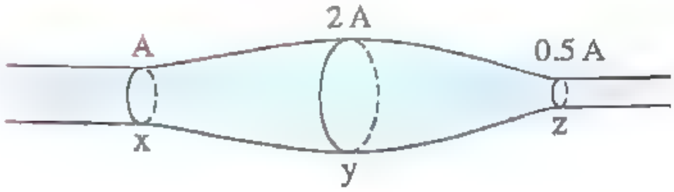
(3) The end of a tube tapers to a narrow opening concerning the speed of the steady flow of the liquid?

# New Types of questions ?

Understand  Apply  Higher Order Thinking Skills

**First : Choose two correct answers in each of the following :**

**1** The opposite figure shows a tube through which a liquid flows steadily, if the speed of liquid flow at cross-section y equals v, the speed of liquid flow at .................. .




ⓐ cross-section x equals v

ⓑ cross-section x equals $\frac{v}{2}$

ⓒ cross-section x equals 2 v

ⓓ cross-section z equals 2 v

ⓔ cross-section z equals 4 v

---

**2** If a pipe of cross-sectional area 10 $cm^2$ was used to fill a container of volume 3600 L with a liquid through a time interval of 60 minutes, so .................. .

ⓐ the volume flow rate of the liquid from the pipe = $10^3$ $m^3/s$

ⓑ the volume flow rate of the liquid from the pipe = $10^{-3}$ $m^3/s$

ⓒ the volume flow rate of the liquid from the pipe = $6 \times 10^{-3}$ $m^3/s$

ⓓ the flow speed of the liquid through the pipe = 1 m/s

ⓔ the flow speed of the liquid through the pipe = 3.6 m/s

**Second: Put in front of each of the following sentences the type of flow that it expresses:**

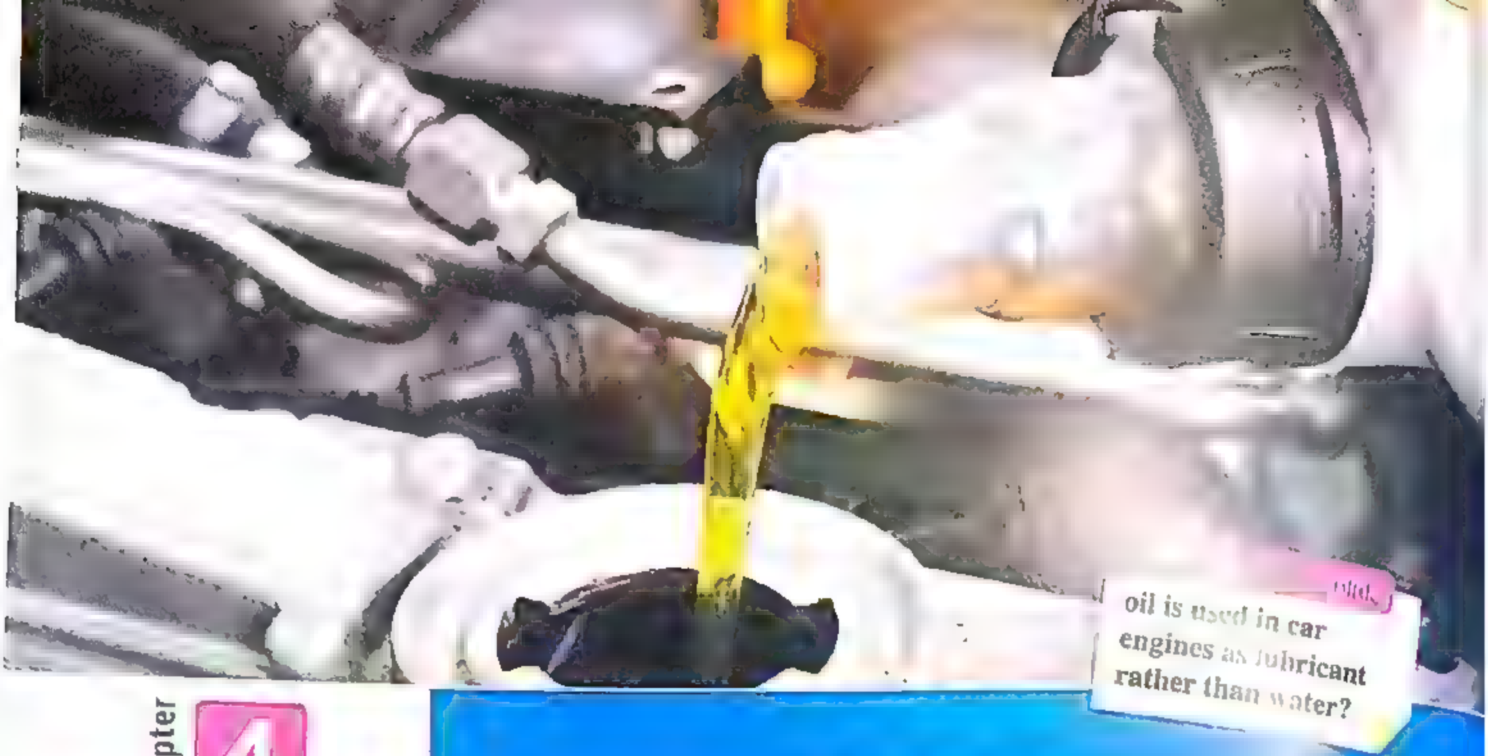
| Steady flow | Turbulent flow |
|---|---|

(1) In which the speed of the liquid at a given point along its path is constant (......)

(2) It is characterized with the presence of eddy currents (......)

(3) It occurs when a gas gets spread from a place of high pressure to a place of low pressure (......)

(4) In which the liquid flow rate is constant along its path (......)




Chapter 4

Lesson Two

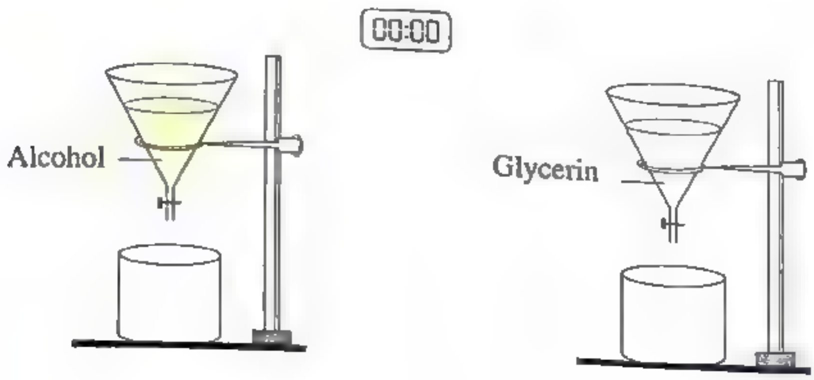
# Viscosity

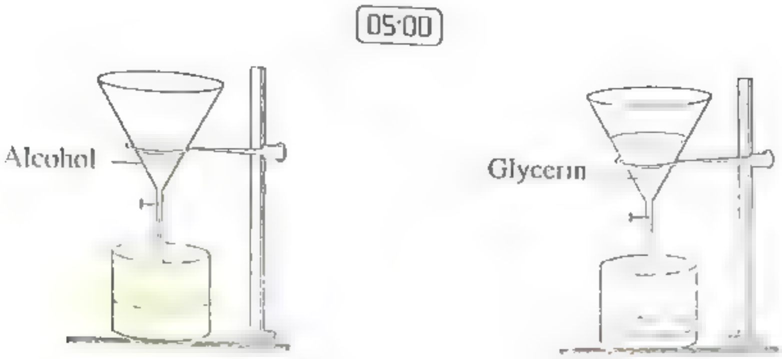
Liquids are characterize by general properties from which is the friction between the liquid layers during its flow. This friction produces a force that resists the sliding of the liquid layers above each other when it flows. This property is known as viscosity, where the concept of viscosity can be clarified through the following activities:

## Activity 1

### Steps:

1. Suspend two funnels on two holders and put two beakers below each of them as shown in the following diagrams.
2. Pour a volume of alcohol in one of them and pour an equal volume of glycerin in the other and observe the flow of the two liquids from the funnels to the beakers.






## Observation :

You will notice that the flow rate of glycerin is less than the flow rate of alcohol.
*i.e.* The ability of flow of glycerin is less than that of alcohol.

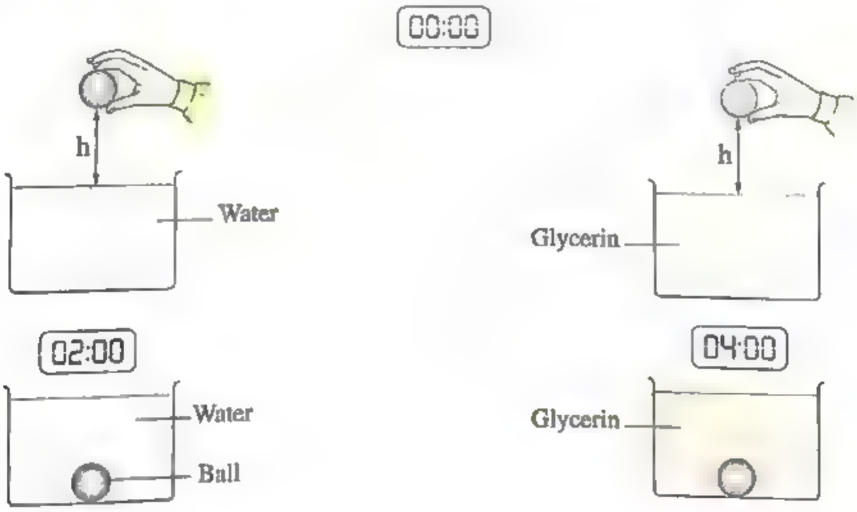
## Conclusion:

The viscosity of glycerin is higher than that of alcohol.

# Activity 2

## Steps:

1. Fill two beakers one with water and the other with glycerin.
2. Drop a small metal ball carefully in each of them from the same height.
3. Record the time taken by each ball to reach the bottom of the beaker.




## Observation:

- You will notice that the ball moves faster in water than in glycerin and reaches the bottom of water before the other ball reaches the bottom of glycerin.

*i.e.* Glycerin resists the motion of the ball more than water.

## Conclusion:

The viscosity of glycerin is higher than that of water.

# Activity 3

## Steps:

1. Fill two beakers one with water and the other with honey.
2. Stir both fluids by a spoon then take out the spoon.


## Observations:

1. You will notice that the spoon moves harder in honey than in water.
2. The motion of honey stops after removing the spoon within a short time interval while water continue to move for a longer time interval.

*i.e.* The resistance of honey to the motion of bodies inside it is greater than that of water.

## Conclusion:

The viscosity of honey is higher than that of water.

**From the previous, we conclude that:**

The higher viscous liquid:

1. shows higher resistance to its own motion and its flow.
2. shows higher resistance to the motion of bodies through it.

**Viscosity can be defined as follows;**

**Viscosity**

It is the property that causes a resistance or a friction between the liquid layers preventing them from sliding smoothly above each other.

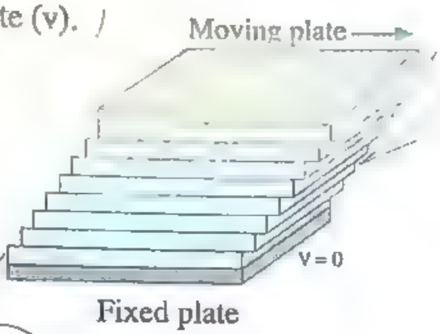
## Explaining the concept of viscosity :

**There are two types of attraction forces between the molecules of matter:**

1. **Cohesive forces:**
   Attraction forces between the molecules of the same substance like the attraction forces between the honey molecules.
2. **Adhesive forces:**
   Attraction forces between the molecules of a substance and the molecules of another substance like the adhesive forces between the molecules of a drop of water and glass.

◎ Imagine a quantity of fluid confined between two parallel plates, one of them is static and the other moves with a velocity v as shown in the figure.

**1** The layer which is adjacent to the moving plate is moving with the same velocity of the plate (v).




**3** The remaining layers between the two plates are moving with velocities [illegible] zero at the fixed plate to v at the moving plate.

**2** The layer which is adjacent to the fixed plate is static.

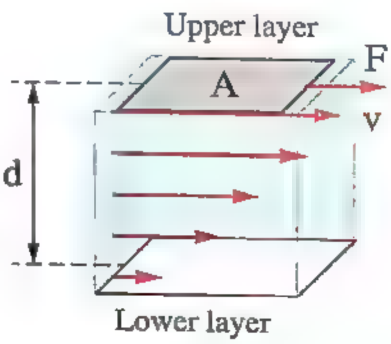
**This happens due to:**

1. The presence of friction between each plate and the adjacent layer of liquid that results from the adhesive forces between the molecules of the solid plate and the molecules of the adjacent liquid layer, so the speed of every layer is equal to that of its adjacent plate.
2. The existence of another force between each liquid layer and the layer below it which resists the sliding of the liquid layers above each other causing a relative change in velocity between each layer and the adjacent layer.

   This type of flow is called the **laminar flow** or **viscous flow**.

## Deducing the viscosity coefficient

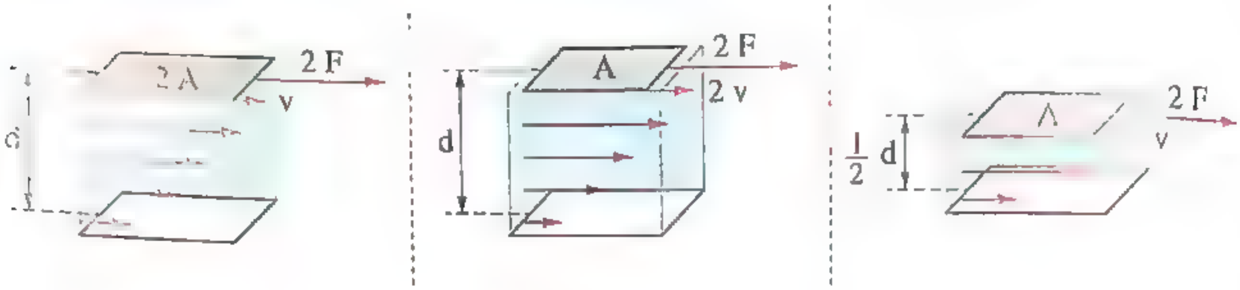
◎ Suppose two layers of a liquid separated by a perpendicular distance d, then a tangential force (F) acts on the upper layer of the liquid that has an area A causing a difference in velocity between the two liquid layers of magnitude v, hence in order to make the moving layer of the liquid keep moving with a constant velocity, the tangential force that acts on the upper layer have to be equal to the frictional forces between the layers of liquid (force of viscosity) and this force is:



① Directly proportional to the area of the moving layer ($F \propto A$)

② Directly proportional to the velocity difference between the two layers ($F \propto v$)

③ Inversely proportional to the perpendicular distance between the two layers ($F \propto \frac{1}{d}$)




$\therefore F \propto \frac{Av}{d}$

$\therefore F = \text{constant} \times \frac{Av}{d}$

$\therefore \boxed{F = \eta_{vs} \frac{Av}{d}}$

$\therefore \boxed{\eta_{vs} = \frac{Fd}{Av}}$

Where: $\eta_{vs}$ is the viscosity coefficient that can be defined as:

**Viscosity coefficient:**

It equals numerically the tangential force that acts upon a unit area of a liquid causing a velocity difference of one unit between two layers separated by a perpendicular distance of one unit.

**The measuring unit of Viscosity coefficient** is $N.s/m^2$ **that is equivalent to** $kg/m.s$ Or $J.s/m^3$

## The factors affecting the viscosity coefficient :

① **Type of the liquid**

② **Temperature of the liquid (The liquid viscosity decreases as its temperature increases)**

**Examples**

At temperature 20°C:

- $(\eta_{vs})_{water} = 10^{-3}\ N.s/m^2$
- $(\eta_{vs})_{glycerin} = 1.5\ N.s/m^2$
- $(\eta_{vs})_{honey} = 10\ N.s/m^2$

Viscosity coefficient of water at temperature:

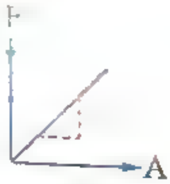
- $t = 20°C \Rightarrow \eta_{vs} = 10^{-3}\ N.s/m^2$
- $t = 100°C \Rightarrow \eta_{vs} = 1.227 \times 10^{-5}\ N.s/m^2$

## The factors affecting

**1** Area of the moving layer.

"Directly proportional"

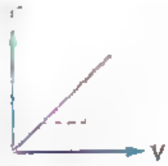
$$\text{Slope} = \frac{\Delta F}{\Delta A} = \eta_{vs} \frac{v}{d}$$




Difference of velocity between the two layers of the liquid

"Directly proportional"

$$\text{Slope} = \frac{\Delta F}{\Delta v} = \eta_{vs} \frac{A}{d}$$

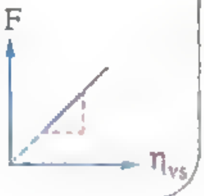



$$F = \eta_{vs} \frac{Av}{d}$$

**3** Viscosity coefficient for many different liquids or one liquid at different temperatures.

"Directly proportional"

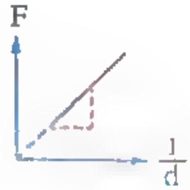
$$\text{Slope} = \frac{\Delta F}{\Delta \eta_{vs}} = \frac{Av}{d}$$




**4** The perpendicular distance between the two layers.

"Inversely proportional"

$$\text{Slope} = \frac{\Delta F}{\Delta\left(\frac{1}{d}\right)} = \eta_{vs}\, Av$$

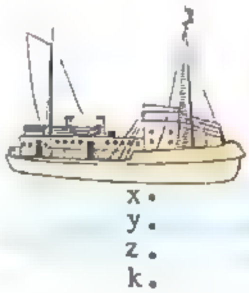



**Example 1**

*In the opposite figure a ship moves in a still water lake, so the water speed is less at point ................ .*

ⓐ x ⓑ y

ⓒ z ⓓ k




**Solution**

The speed of the water layer decreases as we get closer to the static layer at the bottom of the lake.

∴ The lowest speed of water is at point k.

∴ The correct choice is ⓓ.

**Example 2**

*A plane surface of area 0.5 $m^2$ moves at a uniform velocity of 2 m/s parallel to another static surface that is separated from it by a layer of liquid of thickness 4 cm, if the viscosity coefficient of the liquid is 1.5 kg/m.s, then the force required to keep the surface moving with this uniform velocity is ................ .*

ⓐ 37.5 N ⓑ 50 N ⓒ 67.5 N ⓓ 150 N

## Solution

$A = 0.5\ m^2$ | $v = 2\ m/s$ | $d = 4\ cm$ | $\eta_{vs} = 1.5\ kg/m.s$ | $F = ?$

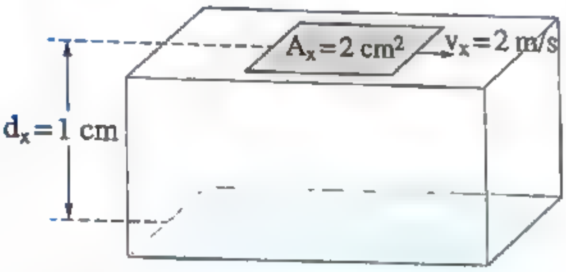
$$F = \eta_{vs}\frac{Av}{d} = \frac{1.5 \times 0.5 \times 2}{4 \times 10^{-2}} = 37.5\ N$$

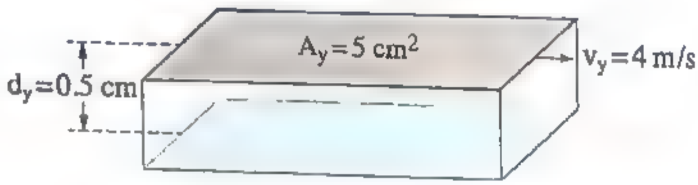
∴ **The correct choice is ⓐ.**

**What if** the temperature of the liquid is increased, **does** the force required to keep the uniform velocity of the plate which is mentioned in the example increase or decrease?

## Example 3

***The following figures show two plane plates x, y each of them is placed above a layer of a liquid. If the force that acts on plate x = The force that acts on plate y, then the ratio between the coefficient of viscosity of the liquid below plate x and that below plate y $\frac{(\eta_{vs})_x}{(\eta_{vs})_y}$ equals ................ .***




ⓐ $\frac{1}{1}$ ⓑ $\frac{1}{10}$ ⓒ $\frac{10}{1}$ ⓓ $\frac{20}{1}$

## Solution

$A_x = 2\ cm^2$ | $v_x = 2\ m/s$ | $d_x = 1\ cm$ | $A_y = 5\ cm^2$

$v_y = 4\ m/s$ | $d_y = 0.5\ cm$ | $F_x = F_y$ | $\frac{(\eta_{vs})_x}{(\eta_{vs})_y} = ?$

$$\because \eta_{vs} = \frac{Fd}{Av}$$

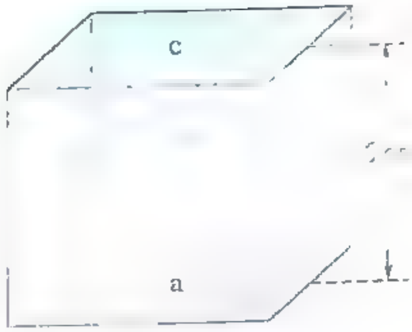
$$\because F_x = F_y$$

$$\therefore \frac{(\eta_{vs})_x}{(\eta_{vs})_y} = \frac{d_x A_y v_y}{d_y A_x v_x} = \frac{1 \times 5 \times 4}{0.5 \times 2 \times 2} = \frac{10}{1}$$

∴ **The correct choice is ⓒ.**

## Example 4

*The opposite figure shows three horizontal parallel plates a, b and c which are placed in a liquid of viscosity coefficient 0.8 kg/m.s. The two plates a, c are fixed while plate b is [illegible] to move and its area equals 4 cm² If plate b is at a distance from one plate twice the distance to the other, then the required force to move plate b with a constant velocity of 5 m/s equals ..................*




ⓐ $2.7 \times 10^{-4}$ N　　ⓑ $1.2 \times 10^{-3}$ N

ⓒ $0.12$ N　　ⓓ $0.03$ N

### Solution

| $\eta_{vs} = 0.8$ kg/m.s | $A_b = 4$ cm$^2$ | $d_{ac} = 6$ cm | $d_{ab} = 2\, d_{bc}$ | $v_b = 5$ m/s | $F_b = ?$ |
|---|---|---|---|---|---|

#### Clue

*Plate b is affected by resistance forces of the liquid from above and below:*

$$\therefore F_b = F_{ab} + F_{cb}$$

$d_{ac} = d_{ab} + d_{bc}$

$6 = 2\, d_{bc} + d_{bc}$

$d_{bc} = 2$ cm

$d_{ab} = 6 - 2 = 4$ cm

$F_b = F_{ab} + F_{cb}$

$$= \frac{\eta_{vs} A_b v_b}{d_{ab}} + \frac{\eta_{vs} A_b v_b}{d_{cb}}$$

$$= \eta_{vs} A_b v_b \left(\frac{1}{d_{ab}} + \frac{1}{d_{cb}}\right)$$

$$= 0.8 \times 4 \times 10^{-4} \times 5 \left(\frac{1}{4 \times 10^{-2}} + \frac{1}{2 \times 10^{-2}}\right) = 0.12 \text{ N}$$

∴ **The correct choice is ⓒ.**

**What if** plate b was in the mid-distance between the plates a, c and moving with the same velocity, **will** the required tangential force to move the plate with the same uniform velocity change?

## Applications of viscosity

### 1. Lubrication of machines.

- Machines should be lubricated from time to time, to decrease the heat produced due to friction and to protect the machine parts from corrosion and increase its efficiency.
- Highly viscous oils are used due to their strong adhesive forces with the machine parts, since they do not seep away or sputter from the machine parts during motion.

**Note :**

- **Water cannot be used in lubrication** because it has low viscosity, so it seeps away from the machine parts due to the weak adhesive force with the machine parts.

### 2. Saving fuel consumption in moving vehicles.

- **The rate of fuel consuming in a moving vehicle depends on:**

1. Motion of the vehicle with an acceleration (changing velocity).
2. Friction forces with:
   - The road.
   - Air (air resistance to the motion of the vehicle).

   When the vehicle moves in a uniform velocity (acceleration = zero), so if this velocity is:

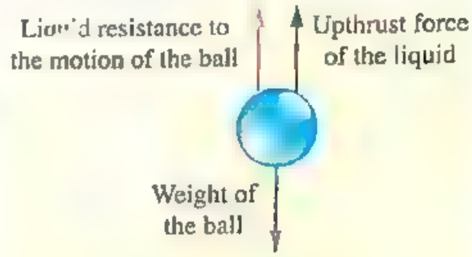
| Low or medium | Higher than a certain limit |
|---|---|
| The air resistance due to air viscosity is directly proportional to the vehicle speed, so the fuel consumption becomes in certain rate. | The air resistance due to air viscosity becomes directly proportional to the square of the vehicle speed, so the fuel consumption becomes much higher. |

So, the expert driver of the vehicle limits the vehicle speed to reduce fuel consumption.

**3. In medicine, blood precipitation rate test (The terminal velocity [illegible] blood cells in plas[illegible]**

When a ball undergoes a free fall in a liquid, it is affected by three forces:

- Its weight.
- Buoyancy (upthrust force) of the liquid.
- Friction between the ball and the liquid due to viscosity.




So, the velocity of the ball increases gradually till it attains a constant terminal velocity due to the balance of these three forces. The terminal velocity increases as the radius of the ball increases, so it can be determined if the volume of the red blood cells was normal or not by taking a blood sample and measuring its precipitation rate which is proportional to the terminal velocity of the falling red blood cells in the plasma, **for example:**

**When**

| The precipitation rate is greater than normal | The precipitation rate is lower than normal |
|---|---|

**it indicates that**

| Red blood cells adhere together, so their volume and radius increase. | Red blood cells break down, so their volume and radius decrease. |
|---|---|

**so, the terminal velocity of blood cells**

| becomes higher | becomes lower |
|---|---|

**like the case of**

| Rheumatic fever | Anemia |
|---|---|

## Test yourself

Answered

1 ✻ Is it better to design ships with large bottom area or with the smallest possible bottom area? **Explain your answer.**

................................................................................................................................................

................................................................................................................................................

................................................................................................................................................

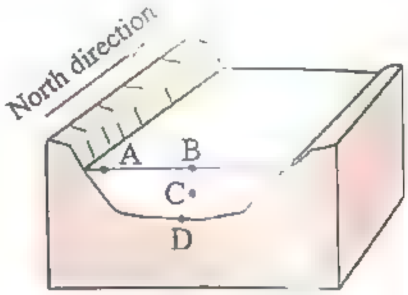
................................................................................................................................................

**2** Choose the correct answer:

(1) A square plate of side length d moves with a uniform velocity of x m/s on the surface of a liquid of depth 2 d when it is affected by a tangential force x newton, so the viscosity coefficient of the liquid equals .......... $kg.m^{-1}.s^{-1}$

ⓐ $\frac{1}{2d}$ ⓑ $\frac{d}{2}$ ⓒ $\frac{2}{d}$ ⓓ $\frac{2}{d^2}$

(2) The opposite figure shows a cross-section in the Nile River. In this section the river flows to the north. At which of the shown points in the figure is the greatest flow speed?




ⓐ At point A. ⓑ At point B.
ⓒ At point C. ⓓ At point D.

(3) A plate of area A slides with uniform velocities on the water surface in two cases as shown in the figures (1), (2), so the ratio between the forces ($\frac{F_1}{F_2}$) that are required to keep the plate moving in the same velocity in each case equals .......... .

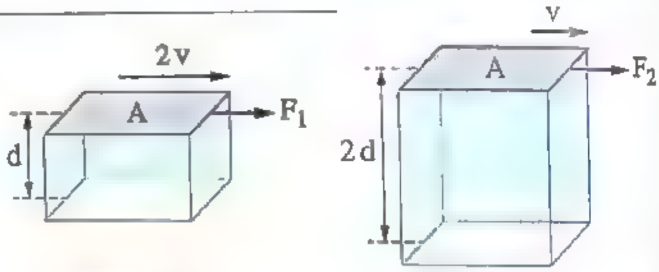



**Figure (1)** **Figure (2)**

ⓐ $\frac{1}{1}$ ⓑ $\frac{1}{2}$ ⓒ $\frac{2}{1}$ ⓓ $\frac{4}{1}$

## Enrichment information :

**Why does a plane fly and not fall?**

The motion of a plane forms a region over the wings where the pressure is less than that below the wings, so an upthrust develops to balance out with the weight of the plane, this phenomenon is called Bernoulli's effect.

**The normal precipitation rate:**

The normal precipitation rate for the red blood cells ranges between 0 : 22 mm/h for men and 0 : 29 mm/h for women.

Chapter 4

Questions on Lesson T

# Viscosity

To watch videos of how to solve questions use the App

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The questions signed by ✳ ~ High Order Thinking Skills

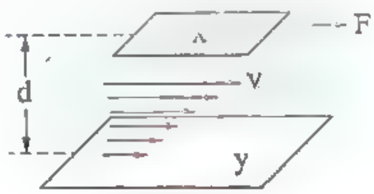
## Multiple choice questions

1. The resistance of a liquid to the motion of objects inside it is a result of ......... .
   (a) the liquid density
   (b) the liquid viscosity
   (c) the weight of the liquid
   (d) the buoyant force of the liquid

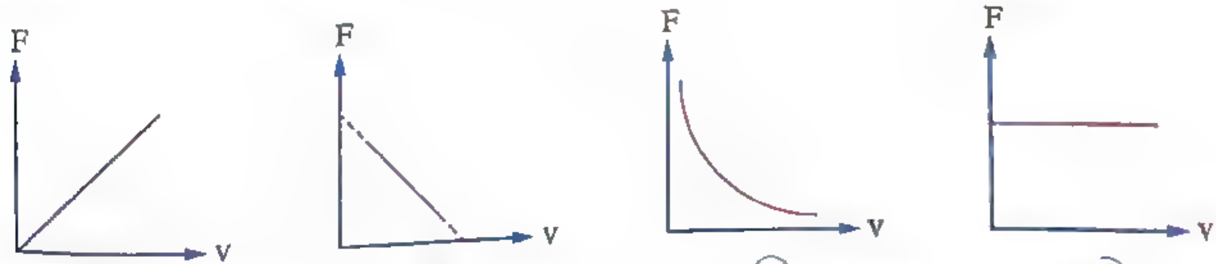
2. If the speed difference between two liquid layers gets decreased when a tangential force is acting on the upper layer, then at the same temperature the viscosity coefficient .... ..... .
   (a) vanishes
   (b) decreases but doesn't vanish
   (c) increases
   (d) remains constant

3. When the temperature of a liquid decreases, its viscosity coefficient ......... .
   (a) increases
   (b) decreases
   (c) does not change
   (d) depends on the type of liquid

4. Which of the following graphs represents the relation between the force (F) which is required to move plate x with a uniform velocity v on the surface of a liquid parallel to a static plate y and the speed (v) of plate x?




Static plate




(a) (b) (c) (d)

5. When a metallic ball falls through a fluid in a jar, the viscosity force of the liquid which is acting on the ball depends on ......... .
   (a) the ball radius
   (b) the liquid density
   (c) the ball mass
   (d) the liquid quantity

6. ✱ When a swimmer jumps into water and reaches a certain depth then rise again to the surface, the force that changes its direction will be .......... .

(a) the swimmer weight

(b) the frictional force between the swimmer and water

(c) the buoyant force of water that acts on the swimmer

(d) all of these forces

7. A metallic ball has fallen once through water and another time throug[illegible] If the average frictional force between the ball and water is $F_1$ and between the ball a[illegible] is $F_2$, then which of the following statements for $F_1$, $F_2$ is correct?

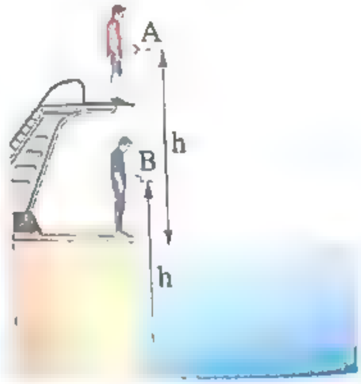
(a) $F_1 = F_2 = 0$ (b) $F_1 = F_2 \neq 0$ (c) $F_1 > F_2$ (d) $F_1 < F_2$

8. During the free fall of a body from the top of a building towards the ground, the [illegible]ctional force between the body and air .......... .

(a) decreases (b) increases

(c) doesn't change (d) decreases then increases

9. If metal ball A takes a time interval t falling from a given height h till it reaches the water surface as shown in the opposite figure, so metal ball B will reach the bottom of water through a time interval .......... .



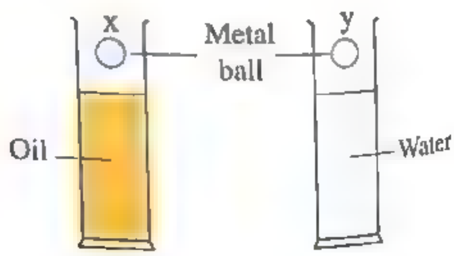

(a) t, because it covers the same distance

(b) less than t because the viscosity of water is less than that of air

(c) greater than t because the viscosity of water is greater than that of air

(d) greater than t because the weight of the ball is greater in water

10. The opposite figure shows two identical metal balls (x, y) falling from the same height into two identical jars containing similar volumes of oil and water till reaching the bottoms, then the average speed of ball x is .......... .




(a) greater than the average speed of ball y

(b) less than the average speed of ball y

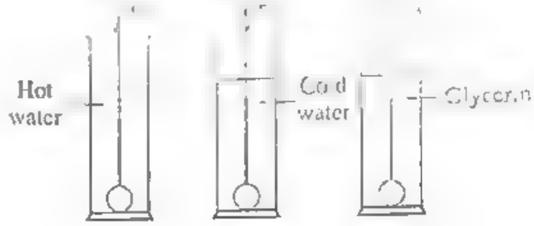
(c) equal to the average speed of ball y

(d) equal to its instantaneous speed at the bottom of the jar

11. A viscous liquid flows steadily in a cylindrical tube. If the liquid speed along the tube axis is v, then the speed of the liquid layer which touches the tube walls equals ........ .

ⓐ 2 v ⓑ v ⓒ $\frac{v}{2}$ ⓓ zero

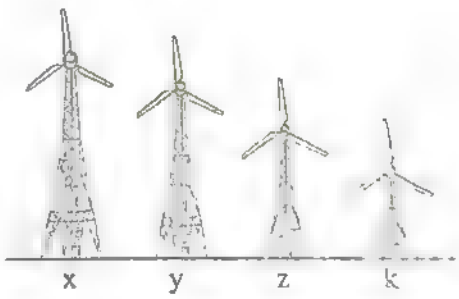
12. The opposite figure shows three identical metal balls, each of them is tied by a thread and placed at the bottom of one of three similar cylinders that contain three equal volumes of different liquids. Through which of these liquids the ball faces a greater resistance when it gets pulled out from the liquid with the same uniform speed?




ⓐ In the hot water. ⓑ In the cold water.

ⓒ In glycerin. ⓓ The same force in all cases.

13. The opposite figure shows four windmills of identical turbines and blades installed near each other at different heights to be used for generating electricity, so the windmill that has the greater potential of generating electricity will be ........ .




ⓐ x ⓑ y

ⓒ z ⓓ k

14. At relatively low or medium speeds of a car, the air resistance due to air viscosity is ........ .

ⓐ directly proportional to the square of the speed of the car
ⓑ directly proportional to the speed of the car
ⓒ inversely proportional to the square of the speed of the car
ⓓ inversely proportional to the speed of the car

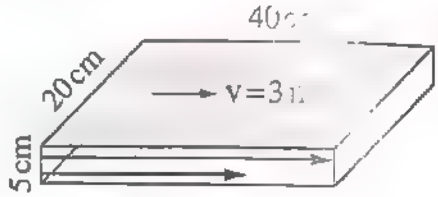
15. At high speeds of a car, the air resistance due to air viscosity is ........ .

ⓐ directly proportional to the speed of the car
ⓑ inversely proportional to the speed of the car
ⓒ directly proportional to the square of the speed of the car
ⓓ inversely proportional to the square the speed of the car

16) Two cars (x, y) have travelled for the same distance with different speeds of 20 km/h and 160 km/h respectively. If the amount of fuel consumed in car x to cover this distance is Q, then the amount of fuel consumed in car y to cover the same distance is .......... .

ⓐ equal to Q
ⓑ greater than Q
ⓒ less than Q
ⓓ indeterminable

17) ✱ In the opposite figure, if a tangential force of 10 N acted upon the upper plate to move it at a uniform speed of 3 m/s, then the viscosity coefficient of the liquid equals .......... .




ⓐ 0.021 $N.s/m^2$
ⓑ 0.48 $N.s/m^2$
ⓒ 0.75 $N.s/m^2$
ⓓ 2.08 $N.s/m^2$

18) A circular plate of radius 7 cm slides at a uniform speed of 0.1 m/s on a ceramic floor covered with a layer of viscous liquid of thickness 2.5 mm and viscosity coefficient 2.5 $N.s/m^2$, then the tangential force acting on the plate is .......... .

ⓐ 1.54 N
ⓑ 1.32 N
ⓒ 1.24 N
ⓓ 1.12 N

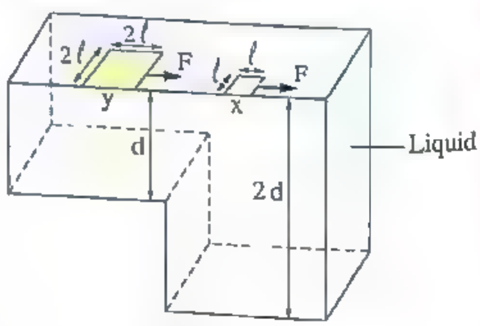
19) A rectangular plate of dimensions 50 cm, 25 cm is affected by a tangential force of 15 N which moves it at a constant speed of 0.8 m/s on a layer of viscous liquid of thickness 9.375 mm, so the viscosity coefficient of the liquid is .......... .

ⓐ 0.42 kg/m.s
ⓑ 0.85 kg/m.s
ⓒ 1.41 kg/m.s
ⓓ 2.31 kg/m.s

20) When a tangential force F acts on a plate of area A placed on another static plate where a layer of liquid of thickness d is in between, the upper plate moves with a uniform velocity v. What is the tangential force that makes the upper plate moves with a constant velocity 2 v under the same conditions?

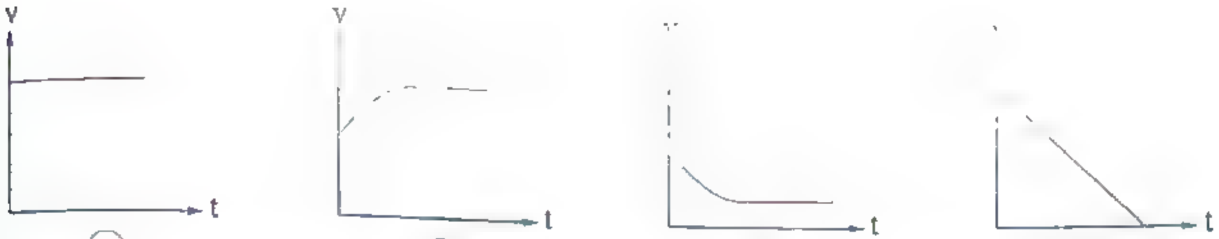
ⓐ F
ⓑ 2 F
ⓒ $\frac{F}{2}$
ⓓ $\frac{F}{4}$

21) ✱ Two plates x, y move on the surface of a liquid with constant velocities $v_x$, $v_y$ respectively by the effect of constant tangential forces of equal magnitudes F as in the opposite figure, then the ratio between the two speeds $\left(\frac{v_x}{v_y}\right)$ equals .......... .




ⓐ $\frac{1}{1}$
ⓑ $\frac{1}{2}$
ⓒ $\frac{1}{8}$
ⓓ $\frac{8}{1}$

22 When a small metal ball is dropped from a certain height into the sea, the graph that represents correctly the relation between the ball speed (v) inside water and time (t) is ........ .




(a) (b) (c) (d)

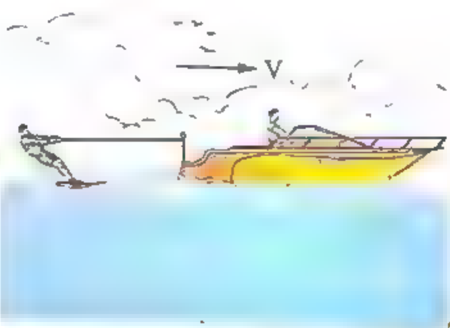
23 ✱ A layer of a viscous liquid of thickness 8 cm is put between two parallel horizontal plane plates. If the viscosity coefficient of the liquid is 0.8 kg/m.s, then the force required to move a thin plate of area 0.5 $m^2$ between the two plates, parallel to them with a uniform speed of 2 m/s and at a distance of 2 cm from one of them equals ........ .

(a) 13.33 N (b) 26.67 N (c) 40.52 N (d) 53.33 N

24 ✱ A layer of thickness x of a liquid of viscosity 0.2 kg/m.s is confined between two plates, one of the plates is static and the other which has an area of 2 $cm^2$ is moving with a uniform velocity such that it covers a distance 100 x through a time interval of 4 s, so the required force to move the plate equals ........ .

(a) 10 N (b) $10^{-3}$ N (c) $10^{-4}$ N (d) 0.1 N

25 The opposite figure shows a boat pulling a skater to move with a uniform velocity v, if the tangential force which is acting on the boat is $F_1$ and the tangential force which is acting on the skating board is $F_2$, then ........




(a) $F_1 > F_2$ (b) $F_1 < F_2$

(c) $F_1 = F_2 = 0$ (d) $F_1 = F_2 \neq 0$

## Second Essay questions

1 **Explain the following statements:**

(1) Aqueous plants grow close to the riverbanks.

(2) The speed of the sea waves decreases as they get closer to the shore.

(3) People who are living in high floors feel the wind speed more than those who are living in the ground floor.

(4) As the viscosity of a liquid increases, its resistance to the motion of a solid body inside it increases.

(5) A liquid restores its static condition after while of stirring it.

(6) It is hard to swim against the current in the middle of the river.

(7) Moving an object in water is harder than it is in air.

(8) It is very important to use oil to lubricate the metallic machines regularly.

(9) Engine oils that are used in summer must be more viscous than what are used in winter.

(10) Using materials of high viscosity to lubricate the metallic machines.

(11) Water is not suitable to lubricate the metallic machines.

(12) The sedimentation rate of red blood cells decreases in anemia patients.

(13) The sedimentation rate of red blood cells increases in rheumatic fever patients.

(14) Doctors can diagnose some diseases through sedimentation rate test.

**2** What are the results of each of the following, give reasons:

(1) Increasing the area of a plate that moves with a constant speed in a viscous liquid to the double, concerning the required tangential force to move the plate.

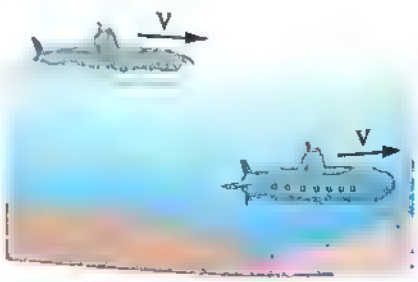
(2) Decreasing the temperature of a liquid, concerning its viscosity.

(3) Not lubricating the moving machines regularly.

(4) Exceeding a certain limit for the car speed, concerning the fuel consumption.

**3** During a Nile cruise from Aswan to Cairo the ship captain sails the ship in the middle of the river stream but during the return from Cairo to Aswan he sails close to the shore. **How do you explain this?**

**4** **In which case** does the submarine need a larger force to push it inside water with a given uniform velocity, while floating or diving inside water?

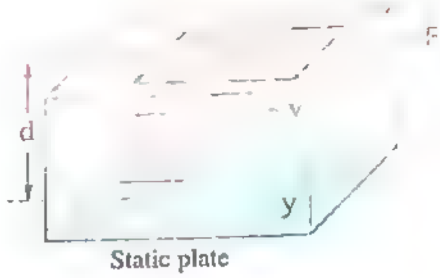


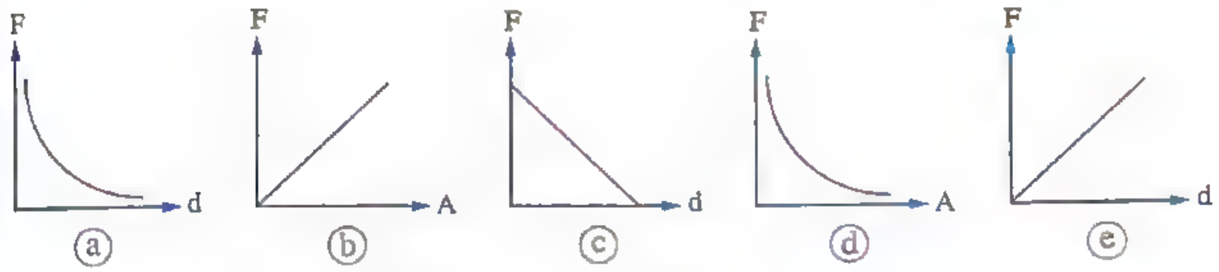
# New Types of questions

Understand  Apply  Higher Order Thinking Skills

**First : Choose two correct answers in each of the following :**

**1** Which of the following graphs represent the force (F) required to move a plate of area A in a liquid with a uniform velocity v parallel to another static plate that is at distance d from it versus one of these factors?



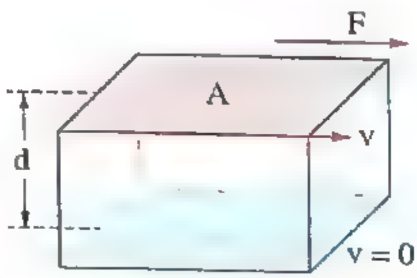




**2** The opposite figure shows a plate of area A sliding under the effect of a force F over a liquid layer on top of another static plate, so when increasing the force (F) affecting the upper plate, then .............. .


ⓐ the liquid viscosity coefficient increases
ⓑ the liquid viscosity coefficient decreases
ⓒ the liquid viscosity coefficient remains unchanged
ⓓ the velocity difference between the two plates increases
ⓔ the velocity difference between the two plates decreases

**Second: From the shown figure answer the following:**

- Put the change that could happen to the liquid viscosity coefficient (**increase, decrease or no change**) in front of each of the following changes in the conditions for a plate of area A moving with a uniform velocity v over a layer of viscous liquid of thickness d:




(1) Increasing the area (A) of the moving plate (......)
(2) Increasing the temperature of the liquid (......)
(3) Decreasing thickness (d) the liquid layer (......)
(4) Increasing the uniform velocity (v) of the moving plate (......)

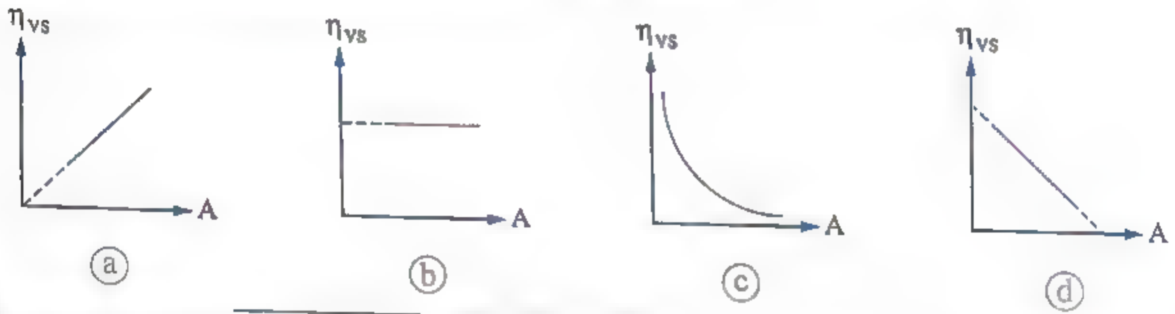
## Test on Chapter 4 Hydrodynamics

### First Choose the correct answer

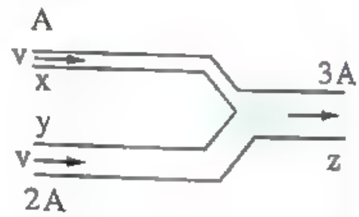
1. Water flows steadily in a pipe that is connected to a hose. If the ratio between the radius of the hose and the radius of the pipe is $\frac{2}{3}$, the ratio between the speed of water in the hose to the speed of water in the pipe is ......... .

ⓐ $\frac{4}{9}$ ⓑ $\frac{2}{3}$ ⓒ $\frac{9}{4}$ ⓓ $\frac{3}{2}$

2. Which of the following graphs represents the variation of the viscosity coefficient ($\eta_{vs}$) of a liquid versus the change of surface area (A) of the plate for multiple plates that are moving with a uniform velocity over the liquid surface?




3. The opposite figure shows a liquid flowing steadily in a tube, so ......... .




ⓐ the density of streamlines at x is less than at z
ⓑ the speed of the liquid at y is less than at z
ⓒ the volume flow rate at x is greater than at z
ⓓ the speed of the liquid at z equals its speed at y

4. Three taps are used for filling a basin, hence to fill the basin, the first tap alone takes an hour and the second alone takes a $\frac{1}{2}$ hour while the third takes $\frac{1}{4}$ hour, so the time required to fill the basin using the three taps together will be ...........

ⓐ $\frac{1}{7}$ hour ⓑ $\frac{3}{4}$ hour ⓒ $\frac{7}{9}$ hour ⓓ $\frac{7}{8}$ hour

5. A plate of surface area 0.25 $m^2$ slides at a constant speed of 0.6 m/s above a layer of a viscous liquid of thickness 5 mm. If the viscosity coefficient of the liquid is 0.95 $N.s/m^2$, the tangential force that acts on the plate equals ......... .

ⓐ 14.25 N ⓑ 21.375 N ⓒ 28.5 N ⓓ 42.75 N

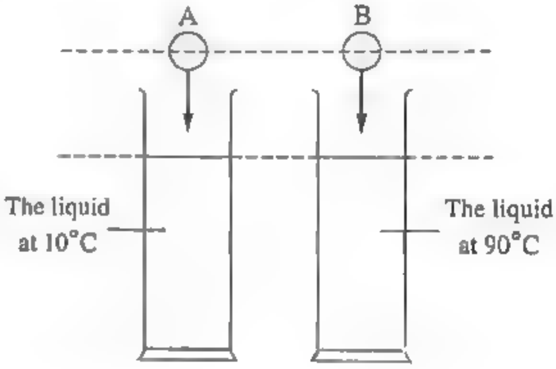
6. Water flows steadily through a horizontal pipe to a narrow section of radius half that of the other section, so the mass flow rate through the narrow section ........ .

ⓐ decreases to quarter
ⓑ decreases to half
ⓒ increases to quadruple
ⓓ remains constant

7. A drip irrigation system is used to drip water through 1000 identical holes, each of cross-sectional area 8 $mm^2$. If the average speed of water flow from each hole is 2 m/s, the volume flow rate in the main tube equals .......... .

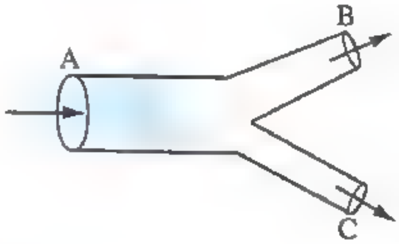
ⓐ 0.08 $m^3/s$
ⓑ 0.016 $m^3/s$
ⓒ 0.32 $m^3/s$
ⓓ 0.064 $m^3/s$

8. The opposite figure shows two metal balls (A, B) falling into two identical cylinders containing equal volumes of the same liquid with different temperatures, which of the two balls reaches the bottom of the cylinder first?




ⓐ Ball A
ⓑ Ball B
ⓒ The two balls reach the bottom at the same instant
ⓓ The two balls will never reach the bottom

9. The opposite diagram shows a liquid flowing steadily in a tube. If the volume flow rates in branches B and C are 0.1 $m^3/s$ and 0.3 $m^3/s$ respectively, the volume flow rate in tube A equals .......... .




ⓐ 0.1 $m^3/s$
ⓑ 0.2 $m^3/s$
ⓒ 0.3 $m^3/s$
ⓓ 0.4 $m^3/s$

10. A hose has a cross-sectional area 25 $cm^2$ at the water source and 5 $cm^2$ at its end. If water flows steadily in the hose with a speed of 0.4 m/s at the water source, the mass of the flowing water through 15 minutes from the hose end equals .......... . ($\rho_{water}$ = 1000 $kg/m^3$)

ⓐ 500 kg
ⓑ 900 kg
ⓒ 2000 kg
ⓓ 2500 kg

## Second Answer the following questions

**11** **What is the effect** of the presence of gas bubbles inside a tube that carries a flowing liquid (concerning the type of flow)?

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**12** A cylindrical syringe is attached to a metallic needle of cross-section 0.1 mm$^2$

**Calculate** the flow speed of the solution through the needle if the flow rate equals $10^{-8}$ m$^3$.s$^{-1}$.

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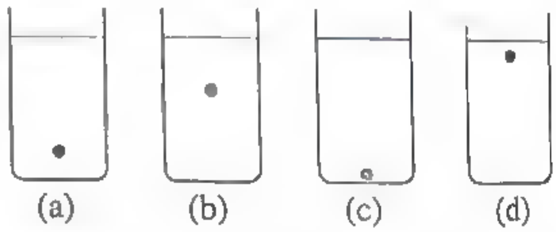
**13** The opposite figures show the positions of metallic balls after 2 s from dropping them from the same height into four different fluids (a, b, c and d).

**Rank the fluids in terms of their viscosities in a descending order with explanation.**

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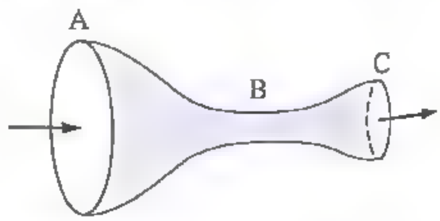
**14** The opposite figure shows a liquid flowing steadily in a tube, **at which section the flow speed of the liquid is higher? And why?**

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15 **Why** is it necessary to use a different type of oil for the car engine in summer than that is used in winter?

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16 A car was travelling with high speed on a desert road when its driver noticed that the fuel was about to run out, **what** is the best strategy to save the fuel until reaching the nearest fuel station, considering what you have studied?

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17 In the human body, blood runs from the heart to the aorta which branches out into main arteries then into small arteries until reaching the blood capillaries. If the radius of the aorta is about 1.2 cm, the blood flow speed inside it is 40 cm/s, the average radius of a blood capillary is about $4 \times 10^{-4}$ cm and the speed of blood inside it is about $5 \times 10^{-4}$ m/s.
**What** is the number of blood capillaries which are branched from this artery?

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# Accumulative Test on Chapters 1, 2 & 4

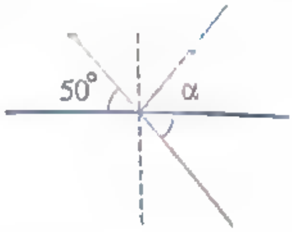
## Choose the correct answer

**1** If the frequency of an oscillatory motion is doubled, the periodic ti

(a) doubled (b) halved (c) quartered (d) ...changed

**2** A light ray is reflected by a plane mirror as shown in the figure.

The angle α equals ..........




(a) 75° (b) 100°

(c) 125° (d) 145°

**3** Water flows steadily through a pipe of diameter 10 cm with a speed of 30 cm/s. The pipe has 5 branches each of the same diameter. One of these branches is connected to a cylindrical tank. If water rises in the tank by a rate of 0.3 cm/s, the tank's diameter equals ..........

(a) 22.4 cm (b) 44.7 cm (c) 66.9 cm (d) 88.2 cm

**4** A liquid flows with a speed of 2 m/s inside a tube of internal diameter 1.2 cm. If the mass flow rate of the liquid equals $159 \times 10^{-3}$ kg/s, the density of the liquid equals ..........

(a) 176 $kg/m^3$ (b) 353 $kg/m^3$ (c) 703 $kg/m^3$ (d) 937 $kg/m^3$

**5** A boy is standing beside to a train rails. He puts his ear on the steel rails to hear the train coming. If the boy hears the train sound through the rails 2.1 s before hearing it through the air, so the train is .......... far away from the boy.

(The speed of sound in the rails is 20 times that in air where in air $v_a = 340$ m/s)

(a) 680 m (b) 751 m (c) 893 m (d) 992 m

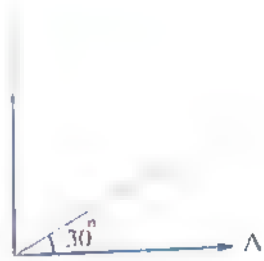
**6** A thin prism of an apex angle of 9° has a refractive index 1.54 for yellow light and 1.72 for blue light, the dispersive power for the prism equals ..........

(a) $\frac{1}{2}$ (b) $\frac{1}{3}$ (c) $\frac{2}{3}$ (d) $\frac{3}{2}$

7. A tank of water is filled by opening the valves a and b of two water pipes in 20 minutes. If valve b was closed, the tank gets filled in 45 minutes, so if valve a is closed and valve b is opened the tank gets filled in ..........


(a) 22 minutes (b) 28 minutes
(c) 36 minutes (d) 45 minutes

8. The graph shows the relation between the angle of deviation ($\alpha_o$) and the apex angle (A) for a group of thin prisms that are made of the same material. If $\alpha_o$ and A are drawn with the same scale, then the refractive index of that material equals ..........




(a) 1.34 (b) 1.58
(c) 2 (d) 1.6

9. Light of wavelength 0.5 μm (in air) enters the water in a swimming pool. The speed of light in water is 0.75 times its speed in air. The wavelength of this light in water equals ..........

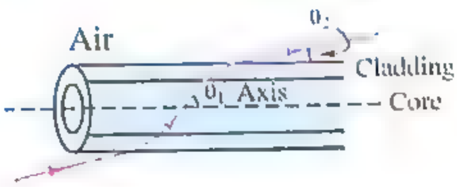
(a) 0.67 μm (b) 0.411 μm (c) 0.5 μm (d) 0.375 μm

10. If blue light in the Young's double slit experiment is replaced by red light, the fringe width will ..........

(a) decrease (b) remain unaffected
(c) increase (d) first increase and then decrease

## Second Answer the following questions

11. A light ray in the core (n = 1.4) of a cylindrical optical fiber falls at an angle $\theta_1 = 49°$ with respect to the axis of the fiber. The ray is transmitted through the cladding (n = 1.2) and into the air. **What** angle $\theta_2$ does the exiting ray make with the outside surface of the cladding?

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(12) A student has got a coherent light source with wavelength 547 nm. He wants to send light through a double slit with a slit separation of 1.5 mm to a screen 90 cm away.
**What** is the minimum width of the screen if the student wants to display five interference maxima (bright fringes)?

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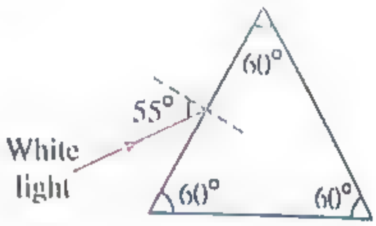
(13) The prism in the figure is made of crown glass. Its index of refraction ranges from 1.517 for the longest visible wavelength to 1.538 for the shortest one.
**Find** the range of refraction angles for the light transmitted into air through the right side of the prism.

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(14) Water flows at speeds v and 2 v through two branches of a pipe to fill two water tanks of volumes L and 3 L respectively. If the two tanks are completely filled within the same time interval, **calculate** the ratio between the diameters of the branches of the pipe.

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(15) A thin glass prism is of angle 7° and refractive indices for blue and red lights 1.66 and 1.55 respectively, **calculate:**

(a) The angular dispersion in the prism.

(b) The deviation angles of red and blue lights.

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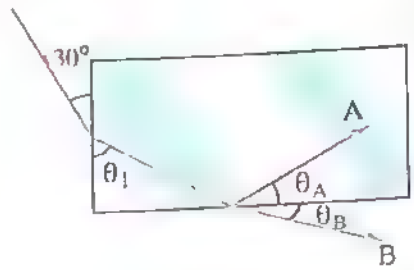
16. A beam of light in air enters a glass block at an angle of 30° to the glass surface, as shown. The glass has an index of refraction of 1.35.




(a) **Find** the angle labelled $\theta_1$.

(b) **Calculate** the critical angle between the glass and air.

(c) **Does** the light follow path A, path B, or both? **Explain.**

(d) **Find** the angle $\theta_A$, if light follows path A and $\theta_B$, if light follows path B.

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17. The following table depicts the relation between the speed of a liquid (v) at a point in a pipe and the cross-section of the pipe at the same point:

| v (m/s) | 60 | 30 | 15 | 6 |
|---|---|---|---|---|
| A ($cm^2$) | 1 | 2 | 4 | 10 |

(a) **Plot** the relation between (v) on the vertical axis and ($\frac{1}{A}$) on the horizontal axis.

(b) **From the graph find:**

1- The speed of the liquid at a cross-section of 5 $cm^2$.

2- The volume flow rate of the liquid.

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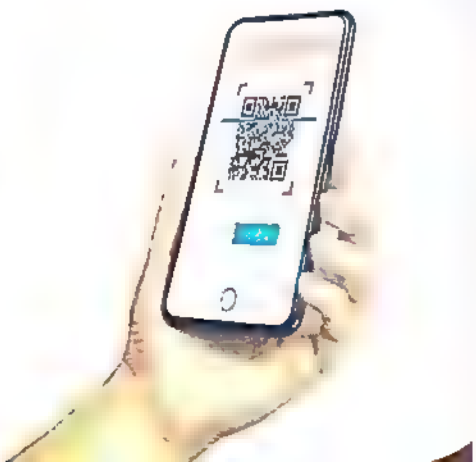
# 10 General Exams

You can reach the exams of some schools and educational administrations by scanning **this QR code**



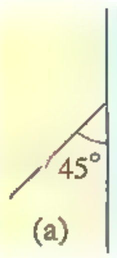
## General Exam 1

### Choose the correct answer (1 : 21)

1. A thin prism has an apex angle 9°, refractive index of 1.72 for the blue light and 1.68 for the red light, then the angular dispersion of the prism equals ................ .

(a) 0.12° (b) 0.24° (c) 0.28° (d) 0.36°

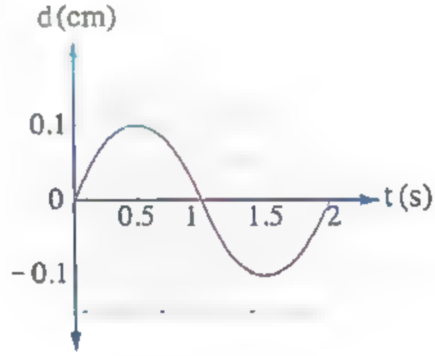
2. In the opposite figure, a light ray falls from medium (a) at angle 45° on the separating surface with medium (b), where it deviates from its original path by an angle of 45°, so the relative refractive index between the two media ($_bn_a$) equals ........................ .




(a) $\sqrt{2}$ (b) $\frac{1}{\sqrt{2}}$

(c) $\frac{\sqrt{3}}{2}$ (d) $\frac{2}{\sqrt{3}}$

3. The opposite (displacement - time) graph represents a body that moves a simple harmonic motion, so ........................ .




| | The amplitude (cm) | The frequency (Hz) |
|---|---|---|
| (a) | 0.1 | 4 |
| (b) | 0.05 | 2 |
| (c) | 0.1 | 0.5 |
| (d) | 0.05 | 0.25 |

4. A layer of a viscous liquid of thickness 3 cm and viscosity coefficient 1.2 kg/m.s is placed between two horizontal parallel plates. If a tangential force of 1.6 N acts on the upper plate to move it with a uniform speed of 1 m/s, then the area of the upper plate equals ........................ .

(a) 200 $cm^2$ (b) 300 $cm^2$ (c) 0.04 $m^2$ (d) 0.05 $m^2$

A liquid flows steadily with speed v through a tube of radius r that ends by a spout of radius 0.5 r, so the speed of the liquid in the narrow end equals .......................... .

(a) 0.25 v (b) 0.5 v (c) 2 v (d) 4 v

If the angle of minimum deviation of a light ray that falls on one of the faces of an equilateral triangular prism is 60°, the refractive index of the prism material for the incident light equals .......................... .

(a) $\sqrt{2}$ (b) 1.5 (c) 1.6 (d) $\sqrt{3}$

In Young's experiment, a monochromatic light of wavelength ($\lambda_1 = 4000$ Å) is used, then the experiment is carried out again with another monochromatic light of wavelength ($\lambda_2 = 7000$ Å). So, the ratio of the separating distance between the centers of two successive fringes of the same type in the two cases $\left(\frac{(\Delta y)_1}{(\Delta y)_2}\right)$ equals .......................... .

(a) $\frac{8}{15}$ (b) $\frac{14}{15}$ (c) $\frac{4}{7}$ (d) $\frac{7}{4}$

If red and blue light rays fall with the same angle of incidence $\phi$ on the separating surface from the optically rarer medium to an optically denser medium, then the ratio between the angle of refraction of red light and the angle of refraction of blue light $\left(\frac{\theta_r}{\theta_b}\right)$ in the optically denser medium is .......................... .

(a) greater than 1 (b) less than 1 (c) equal to 1 (d) indeterminable

The cross-sectional areas of the two ends of a tube are 0.005 $m^2$ and 0.01 $m^2$. If water flows through the tube steadily and the volume of the flowing water within 15 minutes is 9 $m^3$, then .......................... .

| | The speed of the water in the wide cross-section | The speed of the water in the narrow cross-section |
|---|---|---|
| (a) | 0.6 m/s | 1.5 m/s |
| (b) | 1 m/s | 1.5 m/s |
| (c) | 0.6 m/s | 2 m/s |
| (d) | 1 m/s | 2 m/s |

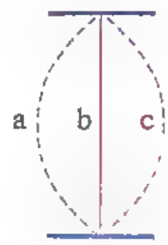
(10) A vibrating object makes 100 complete vibrations through 10 s, hence the frequency of the object equals ........................ .

(a) 10 Hz    12 Hz    30 Hz    60 Hz

(11) In double slit experiment, a light ray falls on the double-slit where the distance between the two slits is 0.19 mm and they are 90 cm away from the observation screen. If the distance between the central fringe and the first bright fringe is $3 \times 10^{-3}$ m, so the wavelength of the used light is ........................ .

(a) 490 nm    (b) 520 nm    (c) 603 nm    (d) 633 nm

(12) The opposite figure represents the motion of a vibrating string, so the velocity of the string is maximum at ........................ .




(a) point a    (b) point b
(c) points b and c    (d) points a and c

(13) Four identical solid balls are dropped from the same height into four cylinders that contain the same amount of different liquids while the time that is taken by each ball to reach the bottom of the cylinder is recorded as the following table:

| Cylinder | Time |
|---|---|
| 1 | 0.2 s |
| 2 | 0.3 s |
| 3 | 0.6 s |
| 4 | 1 s |

Which cylinder contains the liquid of the highest viscosity?

(a) Cylinder 1    (b) Cylinder 2    (c) Cylinder 3    (d) Cylinder 4

14. When a light of wavelength $\lambda$ is used in Young's double-slit experiment, the central fringe is formed at a certain position because the path difference between the two interfered waves at that position is equal to ........................ .

(a) $1.5\,\lambda$  (b) $\lambda$  (c) $0.5\,\lambda$  (d) 0

15. We don't hear the sounds of explosions that happen in the Sun because they are ........................ .

(a) very far  (b) transverse waves
(c) electromagnetic waves  (d) mechanical waves

16. If a light ray transfers from medium a to medium b where the angle of incidence $\phi$ is greater than the angle of refraction $\theta$, the relative refractive index $({}_a n_b)$ is ........................ .

(a) greater than 1  (b) less than 1
(c) equal to 1  (d) the answer is indeterminable

17. A blue light source is immersed under the surface of water at a certain depth to form blue light circular spot on the surface of water. If the blue light source is replaced by a red light source, then the light spot at the water surface ........................ .

(a) vanishes  (b) decreases in area
(c) keeps its area  (d) increases in area

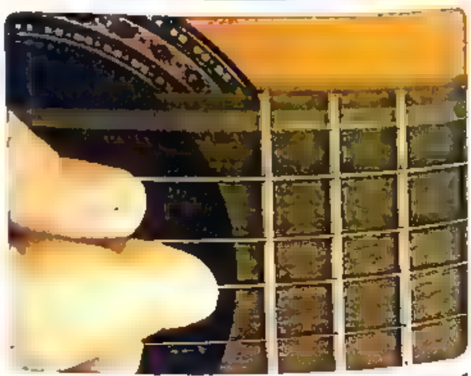
18. If the ratio between the apex angles of two thin prisms of the same material equals $\frac{2}{5}$, then the ratio between the dispersive powers of them respectively equals ........................ .

(a) 1  (b) $\frac{2}{5}$  (c) $\frac{5}{2}$  (d) $\frac{2}{3}$

19. If the volume flow rate of a liquid is $Q_v$ in a pipe that is branched into four branches of the same cross-sectional area, then the flow rate in each branch equals ........................ .

(a) $4\,Q_v$  (b) $\frac{1}{3}Q_v$  (c) $3\,Q_v$  (d) $\frac{1}{4}Q_v$

20. In the opposite figure, a tone of frequency 5000 Hz is produced due to the vibration of a guitar string, then the periodic time of the vibrating string in ms equals ........................ .



(a) $2 \times 10^{-4}$  (b) $5 \times 10^{-4}$
(c) 0.2  (d) 0.5

21 If a light ray falls on one of the faces of a triangular prism of apex angle 40° with an angle of incidence of 60° to emerge normally from the other face, then the refractive index of the prism equals ........................ .

(a) 1.5 (b) 1.41 (c) 1.35 (d) 0.71

## Answer the following questions (22 : 27)

22 A thin prism of apex angle 8° and refractive index 1.5 is totally submerged in water of refractive index $\frac{4}{3}$, **calculate** the angle of deviation of light rays in the prism.

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23 People in the high floors feel wind speed more than those in the lower floors. **Explain why?**

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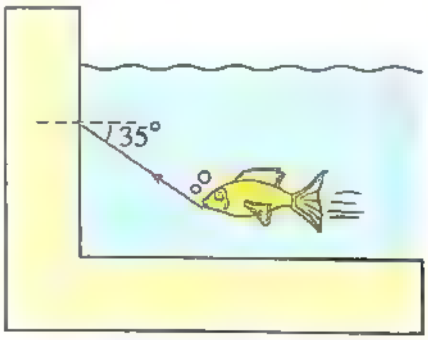
24 A plastic transparent plate of refractive index 1.5 is used to make an aquarium. If a light ray gets reflected from a fish inside the water and falls on the plastic plate at an angle of incidence 35° as in the opposite figure, **calculate** the emergence angle of the light ray to the air. (Knowing that: $n_{water}$ = 1.33)

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25 The opposite figure shows a light ray that falls on a triangular prism of refractive index 1.5, **trace** the path of the light ray in the prism.


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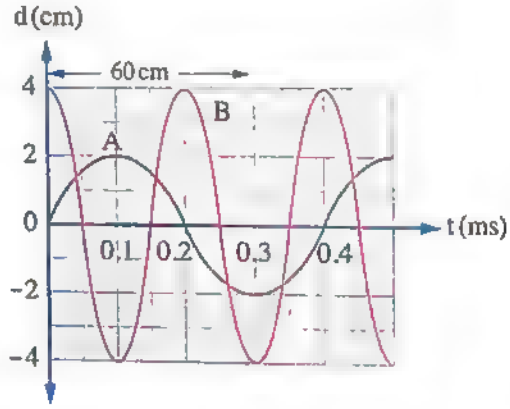
26 The opposite graph shows the relation between the displacement (d) of a particle in a medium and the time (t) for two waves A and B, find the speed of propagation of each wave in the medium.

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27 If the critical angle of water relative to air is 48° and the critical angle of oil relative to air is 44°, **calculate:**

(a) The relative refractive index from water to oil.

(b) The critical angle between water and oil.

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# General Exam 2

## Choose the correct answer (1 - 20)

1. A water pipe of diameter 2.5 cm is used to pour an amount of water of mass 11 kg in a bowl. If it takes 10 s to pour this amount in the bowl, then the speed of the water while emerging from the pipe equals ........................ .
(Knowing that: $\rho_{water} = 1000\ kg/m^3, \pi = \frac{22}{7}$)

ⓐ 2 m/s  2.24 m/s  3 m/s  3.32 m/s

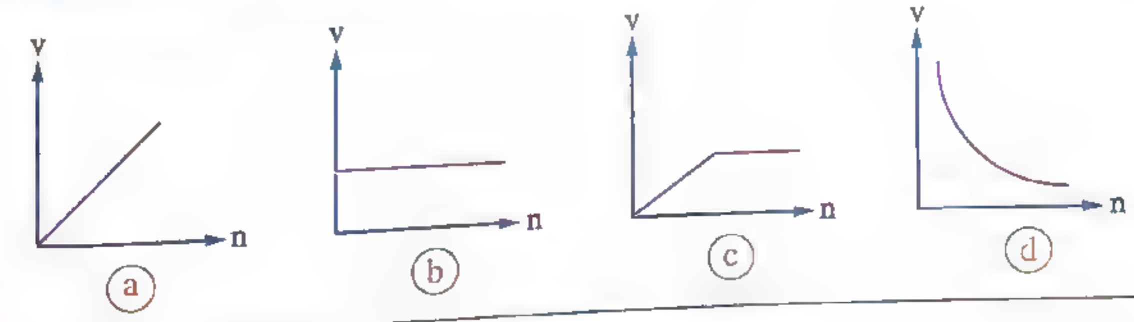
2. If the ratio between the frequency of the sound of a man and the frequency of the sound of a girl is $\frac{3}{4}$, then the ratio between the speed of the man's sound and the speed of the girl's sound in air respectively equals ........................ .

ⓐ $\frac{1}{1}$  ⓑ $\frac{3}{4}$  ⓒ $\frac{4}{3}$  ⓓ $\frac{9}{16}$

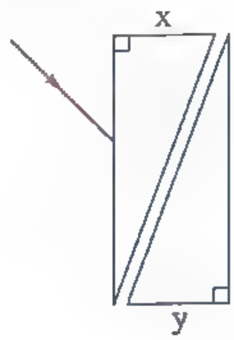
3. A thin prism has apex angle 9°, refractive index for the blue light 1.72 and refractive index for the red light 1.68, hence its average refractive index equals ........................ .

ⓐ 1.66  ⓑ 1.69  ⓒ 1.7  ⓓ 1.71

4. The graph that represents the relation between the speed of light (v) in several media and the absolute refractive index (n) for each of them is ........................ .

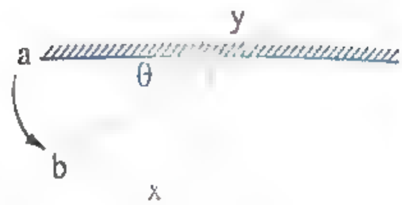



5. In the opposite figure, two prisms x, y of refractive indices 1.5, 1.6 are positioned opposite to each other. If the apex of x is 9° then the apex of y that cancels the deviation of light beam due to prism x equals ........................ .




ⓐ 8°  ⓑ 7.5°
ⓒ 7°  ⓓ 6°

In the opposite figure, a light ray xy falls on a plane mirror in position (a), then the mirror is rotated with angle $\theta$ about an axis perpendicular to the page at the point of incidence to be in the position (b), so the angle of reflection increases by a value of ........................ .

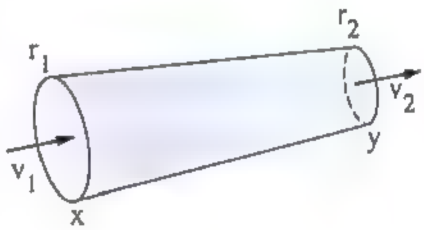



(a) $\frac{\theta}{2}$ (b) $\frac{\theta}{4}$ (c) $\theta$

A hammer beats one end of a very long tube where there is a detector at the other end of the tube that detects two sounds with a time difference between them of 0.2 s. If speed of sound in air is 320 m/s and in the metal is 5000 m/s, then the length of the tube is approximately ........................ .

(a) 17.8 m (b) 34.3 m (c) 49 m (d) 68.4 m

The opposite figure shows a tube that carries a steadily flowing liquid. If the speed of the liquid at the two cross-sections of the tube (x and y) are 0.1 m/s and 0.625 m/s respectively, then the ratio between the radii of the tube $\left(\frac{r_1}{r_2}\right)$ equals ........................ .




(a) $\frac{2}{5}$ (b) $\frac{5}{2}$ (c) $\frac{4}{25}$ (d) $\frac{25}{4}$

In Young's experiment, a blue light of wavelength $\lambda$ passes through two slits where the distance between them is d, so interference fringes appear on the observation screen that is at a distance R from the slits. If another light of wavelength $1.5\ \lambda$ is used, the distance between the two slits should be ........................ to have the same interference pattern.

(a) $\frac{d}{1.5}$ (b) $\frac{d}{0.75}$ (c) 0.75 d (d) 1.5 d

The critical angle between two media of different optical densities is 53.13°. If the absolute refractive index of the denser medium is $\frac{5}{3}$, then the absolute refractive index of the rarer medium is ........................ .

(a) 1.33 (b) 1.51 (c) 1.67 (d) 2.33

(11) A triangular prism of apex angle 45° and refractive index 1.6 is set on the minimum deviation position, so the angle of incidence of the light ray equals ........................ .

(a) 13.8°   (b) 17.3°   (c) 30.5°   (d) 37.8°

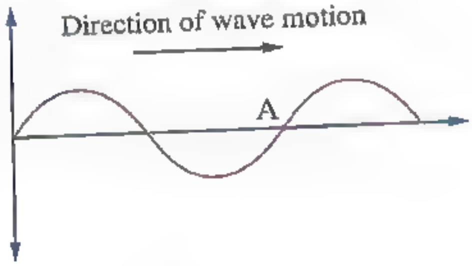
(12) When a light ray transfers from an optically rarer medium to an optically denser medium with an angle of incidence that doesn't equal zero, the light ray ........................ .

(a) reflects on itself
(b) refracts toward the normal
(c) refracts away from the normal
(d) doesn't suffer any deviation

(13) Water flows with speed v through a main pipe that is branched into a number of pipes each of diameter $\frac{1}{15}$ of the main pipe's diameter. So, to keep the speed of flow in the branched pipes the same as in the main pipe, the number of the branched pipes should be ........................ .

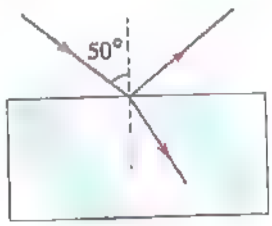
(a) 100   (b) 125   (c) 200   (d) 225

(14) In the opposite figure, point A represents the position of one of the medium molecules in which a transverse wave is propagating at a certain moment. If this point has become a trough after 1.5 s from this moment, so the periodic time of this wave equals ........................ .



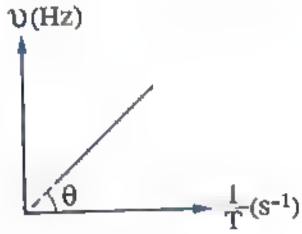

(a) 2 s   (b) 4 s   (c) 6 s   (d) 8 s

(15) The opposite figure represents a light ray that falls on one of the faces of a glass cuboid of refractive index 1.5, so the angle between the reflected ray and the refracted ray equals ........................ .




(a) 93°
(b) 93.9°
(c) 98°
(d) 99.3°

(16) The opposite graph represents the relation between the frequency ($\upsilon$) and the reciprocal of the periodic time ($\frac{1}{T}$) with the same scale for a group of resonant forks that vibrate in air, so the value of θ equals ........................ .




(a) 30°
(b) 45°
(c) 60°
(d) 75°

17. The adjacent fringe to the central fringe in Young's double-slit experiment is ........................ .
    (a) always bright (b) always dark (c) determined by the medium
    (d) determined by the wavelength of the used light

18. The frequency of a wave that propagates through a medium depends on ........................ .
    (a) the amplitude of the wave (b) the source frequency
    (c) the speed of the wave (d) strength of the wave

19. The ratio between the viscosity coefficient of honey in winter and its viscosity coefficient in summer respectively is ........................ .
    (a) greater than 1 (b) less than 1
    (c) equal to 1 (d) indeterminable

20. The dispersion power of a thin prism depends on ........................ .
    (a) the angle of incidence of the beam on the prism
    (b) the intensity of the incident light on the prism
    (c) the apex angle of the prism
    (d) the refractive index of the prism

21. Two parallel light rays, one is blue and the other is green, fall on the boundary surface from an optically denser medium to an optically rarer medium. If the angle of refraction of the green ray is 90°, then the blue ray ........................ .
    (a) refracts towards the normal (b) emerges without suffering any deviation
    (c) refracts away from the normal (d) totally reflects

## Second Answer the following questions (22 - 24)

22. Machines should be lubricated regularly. **Explain why?**

..............................................................................................................................

..............................................................................................................................

23. In Young's experiment, a laser beam of wavelength 575 nm is used. If the observation screen is placed at a distance of 2.75 m from the double-slit, the distance between the center of the central fringe and the center of the first bright fringe becomes 2.75 mm. **Calculate** the distance between the two slits.

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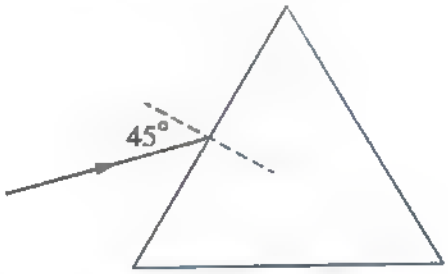
24 What happens to the momentum of a solid body when it falls from air into water?

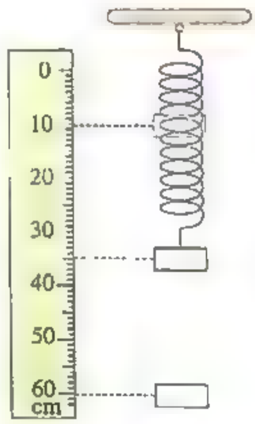
25 In the opposite figure, a light ray falls on an equilateral prism of refractive index $\sqrt{2}$, then find :




(a) The angle of emergence of the ray from the prism.

(b) The angle of deviation of the ray in the prism.

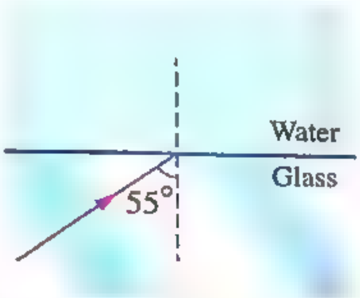
26 A body is suspended in a vertical spring coil besides a ruler where it vibrates between the marks 10 cm, 60 cm. **calculate :**




(a) The amplitude of vibration of the body.

(b) The distance covered by the body during two vibrations.

27 In the opposite figure a light ray falls from glass at an angle of 55° on the separating surface with water. If the absolute refractive indices of glass and water are 1.58 and 1.33 respectively, **will the light ray totally reflect inside glass or emerge to water? And why?**



## General Exam 3

### Choose the correct answer (1 : 21)

1. In Young's experiment a blue light of wavelength $\lambda$ is used to [illegible] two slits where the distance between them is d, so interference fringes [illegible] observation screen which is at a distance R from the slits. If another light of wave[illegible] is used, then to have the same pattern of interference, the observation screen should [illegible] a distance of .................... from the slits.

   (a) $\frac{R}{1.5}$ (b) $\frac{R}{0.75}$ (c) 0.75 R (d) 1.5 R

2. The speed of light in a transparent medium is $2 \times 10^8$ m/s and its speed in another medium is $2.4 \times 10^8$ m/s, then the ratio between the sine of the critical angle of the first medium with air and the sine of the critical angle of the second medium with air $\left(\frac{\sin(\phi_c)_1}{\sin(\phi_c)_2}\right)$ equals .................... .

   (a) $\frac{5}{6}$ (b) $\frac{6}{5}$ (c) $\frac{1}{2}$ (d) $\frac{2}{1}$

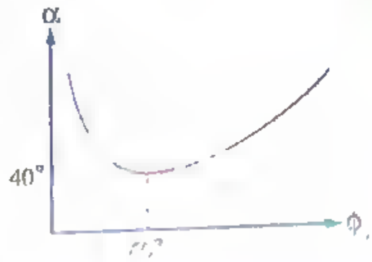
3. A wooden floor is covered with a layer of viscous liquid of thickness 2 mm where a rectangular plate of area 0.12 $m^2$ slides on it with velocity 0.75 m/s when it is affected by a tangential force of 126 N, then the viscosity coefficient of the liquid equals .................... .

   (a) 1.6 N.s/$m^2$ (b) 1.8 N.s/$m^2$ (c) 2.4 N.s/$m^2$ (d) 2.8 N.s/$m^2$

4. A sound wave transfers from air to iron. If the ratio between the speed of sound in air and the speed of sound in iron is $\frac{3}{44}$ while the wavelength of that sound wave in air is 57.6 cm, then its wavelength in iron is .................... .

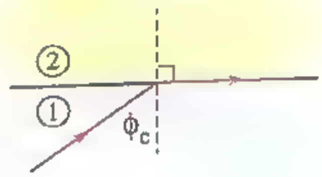
   (a) 4.9 cm (b) 172.8 cm (c) 533.5 cm (d) 844.8 cm

5. The opposite graph shows the relation between the angles of deviation of a light ray ($\alpha$) and the angles of incidence ($\phi_1$) of this light ray on one of the faces of a triangular prism, then the apex angle of the prism and its refractive index are ………… ………… respectively.




(a) 60°, 1.5
(b) 80°, 1.[illegible]
(c) 75°, 1.5
(d) 80°, 1.35

6. In the opposite figure, a light ray falls from a medium on the separating surface with another medium to refract tangent to the separating surface. If the ratio between the speed of light in the first medium and that in the second medium $\left(\frac{v_1}{v_2}\right) = 0.73$, then the critical angle between the two media equals ………… .




(a) 39.65°
(b) 41.8°
(c) 46.89°
(d) 49.72°

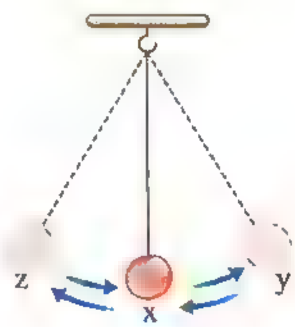
7. When the radius of the cross-section of a tube that carries a steadily flowing liquid increases, the density of the streamlines at the wide cross-section ………… .

(a) decreases
(b) remains constant
(c) increases
(d) the answer can't be determined

8. When the temperature of a liquid decreases, its viscosity coefficient ………… .

(a) increases
(b) decreases
(c) remains constant
(d) depends on the type of the liquid

9. The opposite figure shows the motion of a simple pendulum of periodic time T, so which of the following statements is wrong?




(a) The speed of the load at x > The speed of the load at y
(b) The speed of the load at z = zero
(c) The amplitude = The distance between z and y
(d) The time taken by the load to cover the distance xy = $\frac{T}{4}$

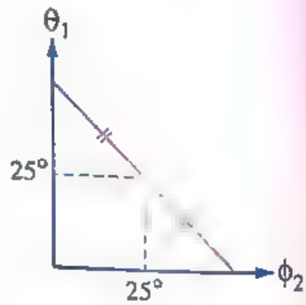
(10) A rock was dropped in a still water of a lake, so it produced 100 waves in 20 s where the diameter of the external circle of the disturbance was 8 m, then ........................ .

| | The frequency of the wave (Hz) | The speed of the wave (m/s) |
|---|---|---|
| (a) | 5 | 0.4 |
| (b) | 5 | 0.2 |
| (c) | 2 | 0.4 |
| (d) | 2 | 0.2 |

(11) A liquid flows steadily in tube x of cross-sectional area 26 $cm^2$ that is branched into two tubes y and z that have cross-sectional areas of 15 $cm^2$ and 7 $cm^2$ respectively. If the speed of the liquid in the tubes x and y are 0.4 m/s and 0.6 m/s respectively, so the speed in tube z equals ........................ .

(a) 0.2 m/s
(b) 0.3 m/s
(c) 0.5 m/s
(d) 0.7 m/s

(12) The opposite figure represents the relation between the first angle of refraction ($\theta_1$) and the second angle of incidence ($\phi_2$) in a glass triangular prism, so the apex angle of the prism equals ........................ .

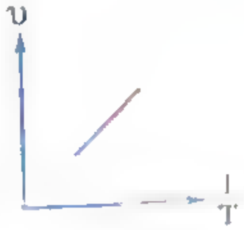



(a) 25°
(b) 45°
(c) 50°
(d) 60°

(13) In the opposite figure, as the boat gets closer to the shore while keeping its speed constant, the athlete needs to ........................ .

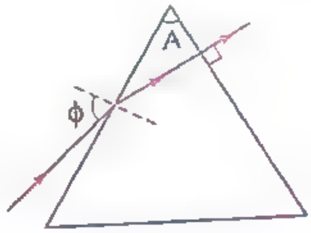
(a) row with a less force
(b) row with a greater force
(c) row with the same force
(d) stop rowing

14 The opposite graph represents the relation between the frequency ($\upsilon$) and the reciprocal of the periodic time ($\frac{1}{T}$) for a body that makes a simple harmonic motion, then the slope equals ........................ .



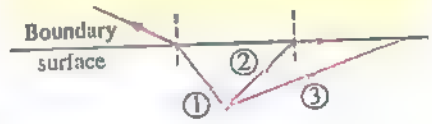

(a) $\frac{1}{2}$
(b) 1
(c) 2
(d) 3

15 A light ray falls on a triangular prism and emerges normal to the other face as in the opposite figure, so the angle of incidence ($\phi$) is ........................ .




(a) greater than A
(b) less than A
(c) equal to A
(d) there is no relation between it and A

16 The opposite figure shows a light source that is placed inside a transparent medium, so what happens to ray ③ at the boundary surface between the two media?




(a) It gets reflected because the angle of incidence is less than the critical angle between the two media
(b) It gets reflected because the angle of incidence is greater than the critical angle between the two media
(c) It gets refracted because the angle of incidence is less than the critical angle between the two media
(d) It gets refracted because the angle of incidence is greater than the critical angle between the two media

17 When the wavelength of a wave that propagates in a certain medium gets doubled, its speed in this medium ........................ .

(a) gets doubled
(b) decreases to its half
(c) decreases to its quarter
(d) remains constant

18. Which of the following is correct when comparing between the refraction and the diffraction of light?

(a) The diffraction happens when light transfers from one medium to another and the refraction happens when light propagates in the same medium

(b) The diffraction happens when light propagates in the same medi... ...nd the refraction happens when light transfers from one medium to ...

(c) Both of them happen when light propagates in one medium

(d) Both of them happen when light transfers from one medium to anoth...

19. When a light wave transfers from one medium to another, the property that ... change for the light wave is the ........................ .

(a) speed (b) wavelength (c) frequency (d) inte...

20. A tube of diameter 10 cm ends with a nozzle of diameter 2.5 cm. If the speed of the water inside the tube is 1 m/s, so the mass of water that flows every minute through any cross-section of the tube equals ........................ .

(Knowing that: The density of water = 1000 kg/m$^3$, $\pi = 3.14$)

(a) 174 kg (b) 147 kg (c) 162 kg (d) 471 kg

21. The factor(s) that affect the angle of deviation of the light ray in a triangular prism is (are) ........................ .

(a) the apex angle of the prism

(b) the angle of incidence of the light ray

(c) the refractive index of the prism

(d) all the previous

## Second Answer the following questions (22 : 27)

22. The opposite figure shows a light ray that falls from air on a transparent glass plate at angle of 45°. **Calculate** the emergence angle of the light ray from the glass plate, if the refractive index of its material is 1.52.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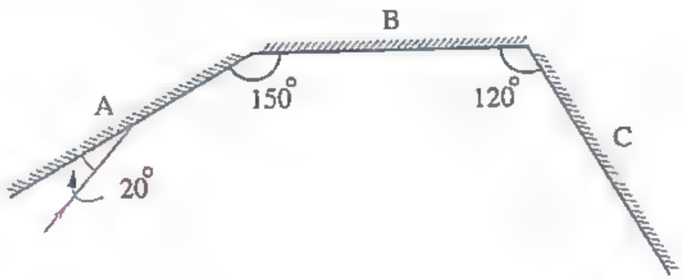
(23) **What happens to** the resolution of the interference fringes when using red light instead of blue light in the double-slit experiment?

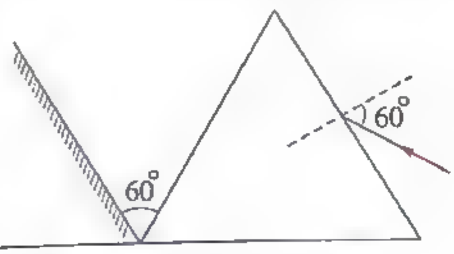
(24) "Every vibrational motion is considered a periodic motion, but not every periodic motion is considered a vibrational motion", **show the validity of** this sentence.

(25) In the following figure, **trace the path of** a light ray that falls on mirror A until it reflects from mirror C.




(26) A light ray falls perpendicularly on one of the faces of a triangular prism of refractive index $\sqrt{2}$ to emerge tangentially to the opposite face, **calculate** the angle of incidence when the prism is rotated to be in the minimum deviation position and also the angle of minimum deviation.

(27) The opposite figure shows an equilateral triangular prism of refractive index 1.5 and a mirror that makes an angle of 60° with one of the prism's faces. **Trace** the light ray until it emerges from the prism, **then find** its angle of its reflection from the surface of the mirror.



# General Exam 4

## Choose the correct answer

**1** The opposite figure shows a light ray that falls on a reflecting surface, so its angle of reflection equals ........................ .


(a) 40° (b) 50°
(c) 60° (d) 90°

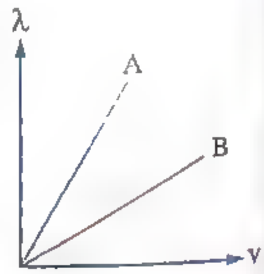
**2** A flat metal plate of surface area 0.0375 $m^2$ slides quickly with a uniform velocity 0.2 m/s on another static plate where there is a liquid layer between them of thickness 3 mm. If the viscosity coefficient of the liquid is 0.25 $N.s/m^2$, then the tangential force that acts on the sliding plate equals ........................ .

(a) 0.55 N (b) 0.625 N (c) 0.732 N (d) 0.78 N

**3** A light ray falls at an angle $\phi$ on one of the faces of a triangular prism of an apex angle 35°, then it emerges perpendicularly from the opposite face. If the refractive index of the prism's material is 1.5, then the value of $\phi$ is ........................ .

(a) 45° (b) 52.47° (c) 59.36° (d) 75°

**4** The opposite graph shows the relations between the speeds (v) of two different waves (A and B) and their wavelengths ($\lambda$) when they propagate through different media, so which of the following relations is correct for the frequency ($\upsilon$) of the two waves?

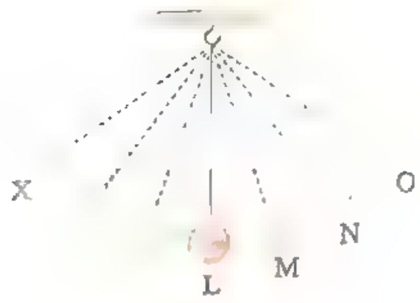



(a) $\upsilon_A < \upsilon_B$ (b) $\upsilon_A = \upsilon_B \neq 0$
(c) $\upsilon_A > \upsilon_B$ (d) $\upsilon_A = \upsilon_B = 0$

**5** If a light ray passes through a slit of width $6 \times 10^{-4}$ mm, then the diffraction resolution will be much better when the wavelength of the light ray equals ........................ .

(a) 400 nm (b) 450 nm (c) 550 nm (d) 650 nm

**6** The opposite figure shows the motion of a simple pendulum from X to O, if the distances NO, MN and LM are equal and the time intervals taken by the pendulum to cover these distances are $T_1, T_2, T_3$ respectively, then which of the following relations is correct?




ⓐ $T_1 = T_2 = T_3$
ⓑ $T_3 > T_2 > T_1$
ⓒ $T_1 > T_2 > T_3$
ⓓ $T_1 + T_2 = T_3$

**7** If the depth of the liquid into which an object falls increases, then the viscosity coefficient of the liquid at constant temperature .......................... .

ⓐ decreases
ⓑ increases
ⓒ remains constant
ⓓ is indeterminable

**8** If the relative refractive index from medium A to medium B is $\frac{1}{\sqrt{2}}$, so the angle of incidence in one of the media that makes the ray emerges to the other medium tangent to the separating surface between the two media equals .......................... .

ⓐ 60°
ⓑ 45°
ⓒ 37°
ⓓ 30°

**9** An artery is branched into 80 capillaries each of radius 0.1 cm. If the radius of the artery is 0.35 cm and the speed of blood flow in it is 0.044 m/s, then the speed of blood flow in each capillary equals .......................... .

ⓐ $3.37 \times 10^{-3}$ m/s
ⓑ $6.74 \times 10^{-3}$ m/s
ⓒ 6.74 m/s
ⓓ 3.37 m/s

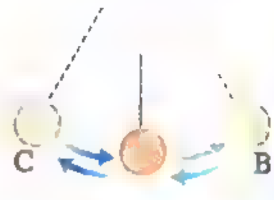
**10** A thin prism of an apex angle 10° deviates the yellow rays that fall on it by an angle of 5°, then the refractive index of its material for the yellow light equals .......................... .

ⓐ 1.45
ⓑ 1.5
ⓒ 1.56
ⓓ 1.59

(11) Water flows steadily with a speed of 0.3 m/s in a tube to fill a tank of volume 30 $m^3$ within 15 minutes, so the cross-sectional area of the tube equals ........................ .

(a) 0.11 $m^2$
(b) 1 $m^2$
(c) 6.67 $m^2$
(d) 60 $m^2$

(12) The opposite figure represents a simple pendulum that moves in a simple harmonic motion, so the ratio between the potential energies of the load at the two positions B and C respectively is ........................ .




(a) $\frac{1}{2}$
(b) $\frac{1}{4}$
(c) $\frac{1}{8}$
(d) $\frac{1}{1}$

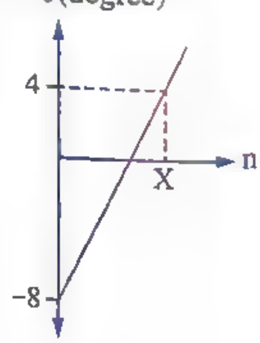
(13) A light ray falls perpendicularly on one of the faces of a triangular prism of an apex angle 38°, then it emerges tangent to the opposite face, so the refractive index of the prism's material is ........................ .

(a) 1.53
(b) 1.59
(c) 1.62
(d) 1.68

(14) The light ray that has the largest critical angle when it travels from water to air is the ........................ ray.

(a) violet
(b) blue
(c) yellow
(d) green

(15) The opposite figure represents the variation of the deviation angle ($\alpha_o$) for a light ray in many thin prisms having the same apex angle versus the refractive index (n) of their materials, so the value of X is ........................ .

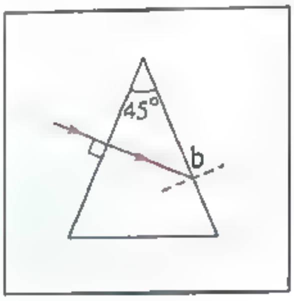



(a) 1.5
(b) 2
(c) 3
(d) 4

16. When a liquid flows steadily, which of the following choices for the volume flow rate and the mass flow rate is correct?

| | Mass flow rate | Volume flow rate |
|---|---|---|
| (a) | Variable | Constant |
| (b) | Variable | Variable |
| (c) | Constant | Constant |
| (d) | Constant | Variable |

17. The opposite figure shows a light ray falls on one of the faces of a triangular prism that is immersed in a liquid of refractive index 1.33. If the critical angle of the prism's material with air is 42°, then the incident light ray at point b ........................ .




(a) gets totally reflected
(b) gets refracted away from the normal line
(c) gets refracted tangent to the face of the prism
(d) gets refracted toward the normal line

18. A light ray falls on one of the faces of an equilateral triangular prism at angle of 40°, and it refracts parallel to the base of the prism, so it emerges at angle of ........................ .

(a) 20° (b) 40° (c) 60° (d) 90°

19. When a light ray falls perpendicularly on the boundary surface between two media, then ........................

(a) $\phi = \theta = 90°$ (b) $\phi = \theta = 0°$ (c) $\phi > \theta$ (d) $\phi < \theta$

20. A light ray falls normal to one of the faces of an equilateral triangular prism, so the second angle of incidence ($\phi_2$) equals ........................ .

(a) 30° (b) 45° (c) 60° (d) 90°

21) If the temperature of a viscous liquid increases, then ..................... .

| | The flow rate of the liquid | The resistance of the liquid against the motion of bodies inside it |
|---|---|---|
| (a) | increases | increases |
| (b) | decreases | increases |
| (c) | increases | decreases |
| (d) | decreases | decreases |

## Second Answer the following questions (22 : 27)

22) A light beam falls on the surface of a transparent material that has a refractive index of 1.55. If the confined angle between the reflected and the refracted rays is 90°, **calculate** the angle of incidence of the light beam. (Knowing that: $\sin (90 - \theta) = \cos \theta$)

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23) A load is attached to a spring of length 7 cm, when it is pulled by a certain force its length becomes 10 cm and then it is left to vibrate. **Calculate** the distance covered by the load during five complete vibrations.

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24) In the same triangular prism the minimum angle of deviation ($\alpha_0$) differs according to the wavelength of the used light. **Explain**.

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25 A lighted lamp is submerged to a depth of 9 cm below the surface of a liquid. If you know that the radius of the smallest cork disk that can be placed on the surface of the liquid where its center is above the lamp and it is enough to block the lamp's light is 12 cm. **Calculate** the refractive index of the liquid.

26 A vibrating body produces a sound and makes a complete vibration every 4 ms, so the sound reaches a man at 136 m from the body 0.4 s later after producing it, **calculate:**

(a) The speed of sound in air.

(b) The distance between the centers of a compression and a successive rarefaction.

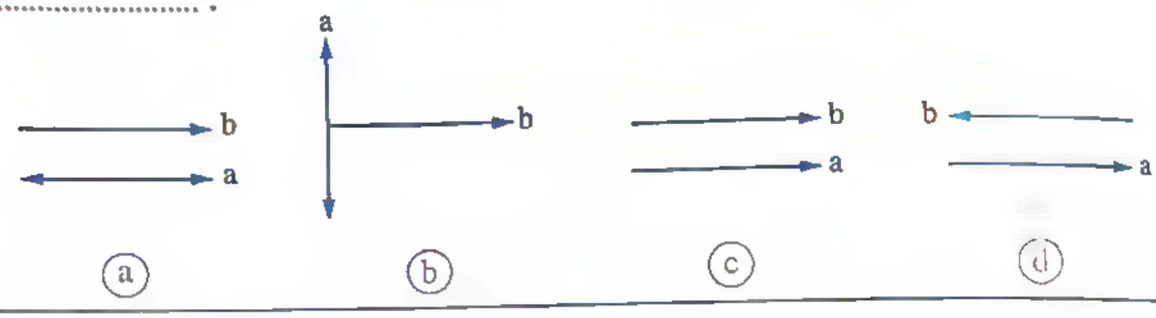
27 A student used a monochromatic light in Young's double-slit experiment. If the distance between the two slits was $8 \times 10^{-5}$ m while the distance between the double-slit and the observation screen of the fringes was 100 cm and the distance between the centers of two successive fringes of the same kind was 6 mm, **calculate** the frequency of the used light.

(Knowing that: The speed of the light in air is $3 \times 10^{8}$ m/s)

# General Exam 5

## First | Choose the correct answer (1 : 21)

1. The figure that represents the direction of the vibration of the particles of medium (a) relative to the direction of the propagation of a transverse wave (b) in this medium is ........................ .



2. The ratio between the first angle of incidence and the angle of emergence of a light ray, that falls on one of the faces of a triangular prism which is at the minimum deviation position, is ........................ .

(a) greater than 1

(b) less than 1

(c) equal to 1

(d) we can't determine the answer without knowing the value of the apex angle of the prism

3. A square plate of side length 10 cm is sliding on another static plate where there is a layer of liquid between them whose coefficient of viscosity is 1.2 $N.s/m^2$. If the upper plate moves with a uniform velocity of 0.2 m/s due to a tangential force of 0.6 N, then the thickness of the liquid layer is ........................ .

(a) 1 mm (b) 2 mm (c) 3 mm (d) 4 mm

4. Two bodies are vibrating, the first body makes 90 complete vibrations in 2 minutes and the second body makes 3 complete vibrations in one second, so the ratio between their periodic times $(\frac{T_1}{T_2})$ equals ........................ .

(a) $\frac{1}{2}$ (b) $\frac{2}{1}$ (c) $\frac{1}{4}$ (d) $\frac{4}{1}$

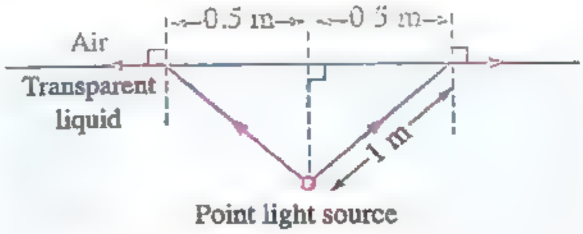
5. At inhalation, the air flows through the trachea with a speed of 15 cm/s. If the cross-sectional areas of each of the two branches of the trachea are quarter that of the main trachea and considering the air flow is steady, then the speed of the air flow in each branch is ........

(a) 7.5 cm/s (b) 15 cm/s (c) 30 cm/s (d) 45 cm/s

6. When carrying out Young's experiment two times using two different light sources where $\lambda_1 > \lambda_2$, then the ratio of the distance between the centers of two successive fringes of the same type in case of the first light to the distance between the centers of two successive fringes of the same type in case of the second light $\left(\frac{(\Delta y)_1}{(\Delta y)_2}\right)$ is ........................ .

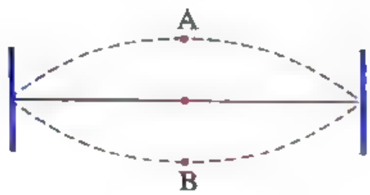
(a) less than 1
(b) greater than 1
(c) equal to 1
(d) can't define the answer

7. The opposite figure shows light rays that are produced from a point light source placed in a transparent liquid. So, the refractive index of this liquid is ........................ .




(a) 1.5 (b) 1.7
(c) 1.8 (d) 2

8. The opposite figure shows a vibrating string. If the time required for the string to move from point A to point B is 0.005 s, then the frequency of the string equals ........................ .




(a) 20 Hz (b) 50 Hz
(c) 100 Hz (d) 200 Hz

9. A thin prism is submerged in water where it deviates the light rays that fall on it from the water by an angle of 0.9°. If the refractive index of the prism's material is 1.5 and the refractive index of water is 1.33, then the apex angle of the prism is .................... approximately.

(a) 8° (b) 7° (c) 6° (d) 5°

10. If the speed of the light rays through a transparent medium is $2.4 \times 10^8$ m/s, then the critical angle of the medium with air equals .................... . ($c = 3 \times 10^8$ m/s)

(a) 39.4° (b) 42.61° (c) 48.2° (d) 53.13°

11. In the double-slit experiment, a student used laser rays of wavelength 632.8 nm and he placed the observation screen 1 m away from the double-slit. He finds that the distance between the center of the first bright fringe and the center of the central fringe is 3.2 mm, so the distance between the two slits is .................... .

(a) 19.8 mm (b) 198 μm (c) 50.6 mm (d) 506 μm

12. The following measuring units are equivalent to each other except .................... .

(a) $kg.m^2/s^2$ (b) $N.s/m^2$ (c) $J.s/m^3$ (d) kg/m.s

13. Firemen use water hoses of narrow nozzles when they extinguish fire because the rushing velocity of .................... .

(a) water increases by decreasing the cross-sectional area of the nozzle
(b) water decreases by decreasing the cross-sectional area of the nozzle
(c) water increases by increasing the cross-sectional area of the nozzle
(d) water is constant whatever the cross-sectional area of the nozzle changes

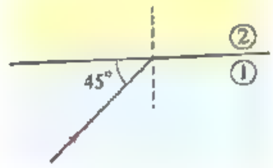
14. When a vibrating body passes by its original rest position, .................... .

| | The magnitude of displacement | The magnitude of velocity |
|---|---|---|
| (a) | maximum | zero |
| (b) | maximum | maximum |
| (c) | zero | zero |
| (d) | zero | maximum |

15. A light ray falls on one of the faces of a triangular prism at an angle of incidence 60°. If the apex angle of the prism is 30° and its refractive index is $\sqrt{3}$, then the light ray ........................ .

(a) emerges tangent to the opposite face
(b) totally reflects and doesn't emerge at the opposite face
(c) emerges normal to the opposite face
(d) changes its path by 90°

16. The opposite figure shows a light ray that falls from medium ① on the boundary surface with medium ②. If it deviates from its path by 45°, the relative refractive index $({}_1n_2)$ will be ........................ .




(a) $\frac{1}{\sqrt{2}}$  (b) $\frac{1}{\sqrt{3}}$  (c) $\sqrt{2}$  (d) $\frac{2}{\sqrt{3}}$

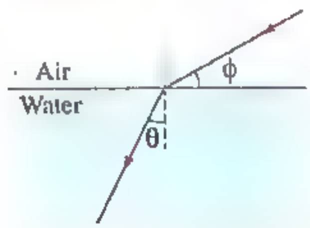
17. If the refractive index of medium A is double the refractive index of medium B, so the ratio between the speed of the light in medium A and the speed of the light in medium B equals ........................ .

(a) $\frac{1}{2}$  (b) $\frac{2}{1}$  (c) $\frac{1}{4}$  $\frac{4}{1}$

18. Light rays fall on two thin prisms, the apex angle of the first prism is double the apex angle of the second prism and the refractive index of the first prism is 1.5 and the refractive index of the second prism is 1.2. So, the ratio between the angle of deviation of the first prism and the angle of deviation of the second prism respectively equals ........................ .

(a) $\frac{10}{1}$  (b) $\frac{20}{1}$  (c) $\frac{5}{1}$  (d) $\frac{1}{2}$

19. The opposite figure represents a light ray that transfers from air to water of refractive index $\frac{4}{3}$, so the relation that represents the refraction in this case is ........................




(a) $\frac{\sin\phi}{\sin\theta} = \frac{4}{3}$  (b) $\frac{\sin\theta}{\sin\phi} = \frac{4}{3}$

(c) $\frac{\sin(90-\phi)}{\sin\theta} = \frac{4}{3}$  (d) $\frac{\sin(90-\phi)}{\sin(90-\theta)} = \frac{4}{3}$

20 When the school's bell rings, its sound reaches the ears of students in the form of .......................... waves.

(a) longitudinal
(b) transverse
(c) longitudinal and transverse
(d) electromagnetic

21 In the diffraction phenomenon, the waves path changes, ..........

(a) when they transfer from a medium to another
(b) when they fall on a reflecting surface
(c) when they encounters a sharp edge
(d) when they collide another wave

## Second — Answer the following questions (22 : 27)

22 It is easier to see your reflected image on the glass window of a lighted room at night when the outside is dark than seeing your reflected image in daytime. **Explain.**

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23 **Draw** on the following graph paper the sine curve that represents two waves of the same kind A and B that propagate in the same medium and have the same amplitude but the frequency of wave A is half the frequency of wave B.

24 In the dispersion of white light into its components using a triangular prism, red light has the least deviation angle and violet light has the largest deviation angle. **Explain.**

........................................................................................................

........................................................................................................

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........................................................................................................

25 If the wavelengths of a specific light ray in two different media A and B are 450 nm and 600 nm respectively, **calculate** the critical angle between the two media and **in which** medium the critical angle is located?

........................................................................................................

........................................................................................................

........................................................................................................

26 An empty tank is filled by an amount of kerosene of mass 100 kg by using a hose where the kerosene emerges from its nozzle with a speed of 0.2 m/s, so the tank is filled during 25 minutes, **calculate** the radius of the hose nozzle.

(Knowing that: Density of kerosene = 900 kg/m$^3$, $\pi$ = 3.14)

........................................................................................................

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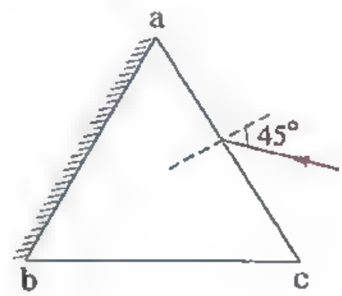
........................................................................................................

27 The opposite figure represents a light ray that falls at an angle of 45° on the face ac of an equilateral triangular prism that has a material of refractive index $\sqrt{2}$ and its external face ab is silvered by a reflecting layer. **Trace** the path of the light ray till it emerges from the prism.

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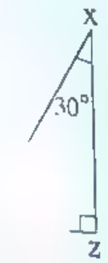
# General Exam 6

## First: Choose the correct answer (1 : 21)

1. The opposite figure shows a light ray falls perpendicular to the face yz of a right angle triangular prism of refractive index 1.6. The prism is submerged in a liquid of refractive index 1.3, then the angle of incidence of the ray on face xy will be ........................ .




ⓐ 90°
ⓑ greater than the critical angle between the prism and the liquid
ⓒ less than the critical angle between the prism and the liquid
ⓓ equal to the critical angle between the prism and the liquid

2. If the angle of minimum deviation of a light ray that falls on one of the faces of an equilateral triangular prism is 30°, then ........................ .

| | The angle of emergence | The refractive index of the prism |
|---|---|---|
| ⓐ | 30° | 1.5 |
| ⓑ | 30° | $\frac{\sqrt{3}}{2}$ |
| ⓒ | 45° | $\frac{\sqrt{3}}{2}$ |
| ⓓ | 45° | $\sqrt{2}$ |

3. When a wave transfers between two different media, then ........................ .

| | The speed of the wave | The frequency of the wave |
|---|---|---|
| ⓐ | remains constant | remains constant |
| ⓑ | remains constant | changes |
| ⓒ | changes | remains constant |
| ⓓ | changes | changes |

4. Water flows steadily in a tube. If the ratio between the diameters of its ends is $\frac{2}{3}$, then the ratio between the mass flow rates of water in them respectively is .......................... .

(a) $\frac{2}{3}$ (b) $\frac{4}{9}$ (c) $\frac{3}{2}$ (d) $\frac{1}{1}$

5. A light ray falls perpendicularly on one of the faces of a triangular prism of refractive index 1.65 and the ray emerges tangent to the opposite face, so the apex angle of the prism is .......................... .

(a) 37° (b) 48° (c) 52° (d) 58°

6. In the steady flow, the ratio between the number of the streamlines in the wide cross-section of the tube and the number of the streamlines in the narrow cross-section of the tube is .......................... .

(a) greater than 1
(b) less than 1
(c) equal to 1
(d) the answer can't be determined

7. In Young's double slit experiment, when a light of wavelength $\lambda$ is used, the distance between the centers of the central fringe and the ninth bright fringe was 1.5 cm. If the wavelength of the used light is changed to 1.5 $\lambda$, then the distance 1.5 cm will be between the center of the central fringe and the center of the .......................... .

(a) third bright fringe
(b) sixth bright fringe
(c) ninth bright fringe
(d) tenth bright fringe

8. A sound source produces 60 vibrations within 1.5 s and the produced wave propagates in air with a speed of 340 m/s, then the distance between the centers of a compression and a successive rarefaction equals .......................... .

(a) 2.8 m (b) 4.25 m (c) 5.67 m (d) 8.5 m

9. If the angular dispersion equalize in two thin prisms, where the apex angle of the first prism is 6° and its refractive indices for the blue and the red light respectively are 1.68 and 1.62 and the apex angle of the second prism is 9° and its refractive index for the blue light is 1.65, then its refractive index for the red light is .......................... .

(a) 1.64 (b) 1.63 (c) 1.62 (d) 1.61

10 Water flows steadily through a tube of inner diameter of 3.5 cm with a speed of 0.8 m/s. If the density of water is 1000 kg/m$^3$, then the mass flow rate equals ........................ .

(a) 0.385 kg/s (b) 0.77 kg/s (c) 1.155 kg/s (d) 1.54 kg/s

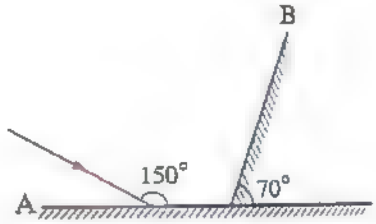
11 A light ray falls at an angle of 45° on one of the faces of a cuboid that is made of a transparent material of refractive index 1.75 and emerges from the opposite face to air, then ........................ .

| | The angle of refraction of the light ray inside the cuboid | The angle [illegible] the light ra[illegible] |
|---|---|---|
| (a) | 32.4° | 45° |
| (b) | 32.4° | 30° |
| (c) | 23.8° | 45° |
| (d) | 23.8° | 30° |

12 In the opposite figure, the angle of reflection of the light ray on the mirror B equals ........................ .

(a) 30° (b) 50°

(c) 60° (d) 90°




13 From the factors that affect the viscosity coefficient, ........................ .

(a) the area of the moving layer from the fluid

(b) the temperature of the fluid

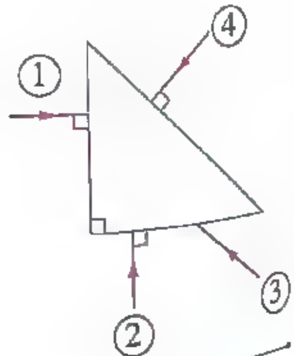
(c) the speed of the fluid

(d) thickness of the fluid layer

14 The opposite figure shows four light rays that fall on an isosceles triangular prism of refractive index 1.5, so which of these rays changes its direction by 180°?

(a) ① (b) ②

(c) ③ (d) ④



15 In the opposite figure, the pendulum makes a half of an oscillation when it moves from position .................. .


(a) x to z
(b) x to y
(c) y to x
(d) y to z

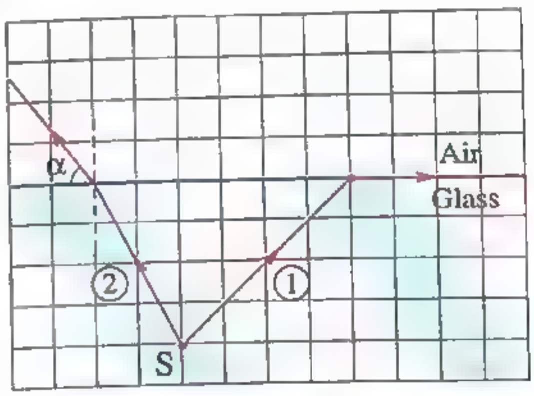
16 If the frequency of a wave in a medium doubles, then its .................. .

(a) wavelength decreases to its half
(b) wavelength doubles
(c) speed decreases to its half
(d) speed doubles

17 The relative refractive index ($_1n_2$) between two media is greater than one in all of the following cases except, when .................. .

(a) the speed of light in the first medium is greater than its speed in the second medium
(b) the angle of incidence in the first medium is greater than the angle of refractive in the second medium
(c) the absolute refractive index of the first medium is smaller than the absolute refractive index of the second medium
(d) the wavelength of light in first medium is smaller than the wavelength of light in the second medium

18 Two light rays (1), (2) are propagating from the source S through glass to the air as represented by the scale which is shown in the figure, then the angle α approximately equals .................. .




(a) 27°
(b) 39°
(c) 45°
(d) 51°

19 The ratio between the deviation angle of the violet light and the deviation angle of the red light is .................. after they emerge from a triangular prism at minimum deviation position.

(a) greater than 1
(b) less than 1
(c) equal to 1
(d) indeterminable

20 In Young's experiment, when a monochromatic light passes through two slits and falls on an observation screen, the fringes that are formed on the screen is due to the .......................... .

(a) reflection (b) refraction (c) interference (d) diffraction

21 The opposite figure represents a liquid that flows steadily in a tube where it enters from terminal A and emerges from terminal B, then .......................... .


(a) the speed of the liquid at A is equal to the speed of the liquid at B
(b) the flow rate of the liquid at A is less than the flow rate of the liquid at B
(c) the speed of the liquid at A is less than the speed of the liquid at B
(d) the flow rate of the liquid at A is greater than the flow rate of the liquid at B

## Second Answer the following questions (22 : 27)

22 In Young's experiment for measuring the wavelength of the red light, the center of the bright fringe of the second order is formed at $4 \times 10^{-3}$ m away from the center of the central fringe. If the observation screen is 200 cm away from the double slit and the distance between the two slits is $7 \times 10^{-4}$ m, **calculate** the wavelength of the red light.

..........................................................................................
..........................................................................................
..........................................................................................
..........................................................................................

23 **What are the conditions** required for the triangular prism to be in the minimum deviation position?

..........................................................................................
..........................................................................................

24 It's noticed that the aquatic plants in the Nile river are found near the riverside and not in the middle of the watercourse. Explain this sentence.

25 A tuning fork is struck, so it makes 2048 complete vibrations in 8 seconds, calculate:

(a) The frequency of the fork.

(b) The periodic time of the produced vibrations.

26 If you have two flexible transparent materials where the refractive index of one of them is larger than that of the other material and we want to use them to make an optical fiber, then which of them is used to make the inner core of the optical fiber and which of them is used to make the external layer of it? And why?

27 A triangular prism of apex angle 45° and refractive index of 1.7 is totally submerged in water of refractive index of $\frac{4}{3}$, **calculate** the angle of emergence and the angle of deviation of the light ray that falls perpendicularly on one of the prism's faces.

# General Exam 7

## First Choose the correct answer (1 : 21)

1. Load is attached to a spring where it is in equilibrium, if the load is pulled downwards for a distance 10 cm then it is left to pass by the equilibrium position for the first time after 0.5 s, then ........................ .

| | The amplitude of the vibration (cm) | The [illegible] (s) |
|---|---|---|
| a | 10 | 1.5 |
| b | 10 | 2 |
| c | 20 | 2 |
| d | 20 | 1.5 |

2. Water flows steadily in a tube of radius 3.5 cm at a speed 3 m/s, then the time required to fill a cubic tank of side length 226 cm approximately equals ........................ . $(\pi = 3.14)$

   (a) 900 s (b) 1000 s (c) 1100 s (d) 1200 s

3. If the critical angle of a light ray that transfers from a medium of refractive index 1.72 to another medium is 55°, then the refractive index of the second medium equals ........................ .

   (a) 1.41 (b) 1.48 (c) 1.53 (d) 1.56

4. A light ray falls on one of the faces of a thin prism of an apex angle 8°, refractive index for the blue light 1.664 and refractive index for the red light 1.644, then the dispersive power for the material of this prism equals ........................ .

   (a) 0.05 (b) 0.04 (c) 0.03 (d) 0.02

5. A light ray falls on one of the faces of a triangular prism of refractive index $\sqrt{2}$ at an angle of 45° and emerges from the opposite side at angle of 45°, then the apex angle of the prism is ........................ .

   (a) 45° (b) 60° (c) 72° (d) 80°

6 In Young's experiment, the distance between the center of the first bright fringe and the center of the central fringe is 2 mm, then the distance between the center of the third dark fringe and the center of the central fringe equals ........................ .

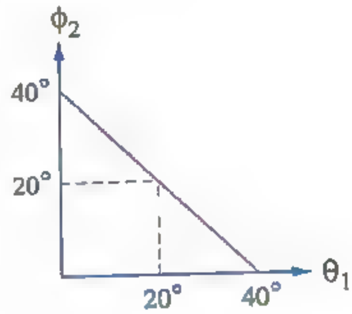
(a) 2 mm   (b) 5 mm   (c) 6 mm   (d) 7 mm

7 The ratio between the periodic time and the frequency of a tuning fork is $\frac{1}{65536}$ $s^2$, then the number of the vibrations that is produced in 10 seconds equals ........................ .

(a) 1636 vibrations   (b) 2560 vibrations

(c) 3160 vibrations   (d) 6320 vibrations

8 The opposite graph represents the relation between the first angle of refraction ($\theta_1$) and the second angle of incidence ($\phi_2$) when a light ray passes through a triangular prism. If the critical angle of the prism material is 41.8°, then the angle of minimum deviation for the falling light ray is ........................ .




(a) 17.27°   (b) 21.73°

(c) 25.46°   (d) 30.25°

9 A light ray falls from air on the surface of a transparent medium at an angle 50°, so part of the ray reflects and another part refracts where the confined angle between the reflected and the refracted rays is 100°, then the critical angle for the transparent material with air is ........................ .

(a) 36.8°   (b) 40.75°   (c) 42.68°   (d) 45.54°

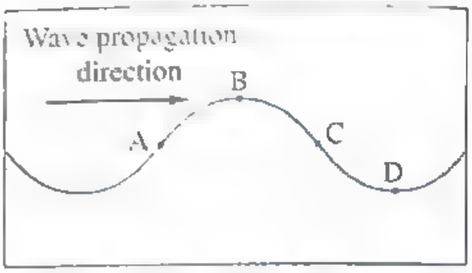
10 A viscous liquid layer of thickness 2.5 mm is covering a ceramic floor. If a square plate of area 0.1 $m^2$ slides on the floor with uniform speed 0.5 m/s due to a tangential force of 35 N, then the coefficient of viscosity of the liquid equals ........................ .

(a) 0.75 $N.s/m^2$   (b) 1.25 $N.s/m^2$   (c) 1.75 $N.s/m^2$   (d) 2.25 $N.s/m^2$

(11) Water sprayer has 20 identical holes each of cross-sectional area 5 $mm^2$, the sprayer is connected to a hose of cross-sectional area of 120 $mm^2$ where the water flows in the hose with a speed of 1.5 m/s, so the speed of the water flow through the holes of the sprayer is ........................ .

(a) 0.05 m/s (b) 0.56 m/s (c) 1.8 m/s (d) 20 m/s

(12) The opposite figure shows a vertical section of a wave propagating through water from left to right, at which two points the instantaneous vertical velocities of water particles are maximum?

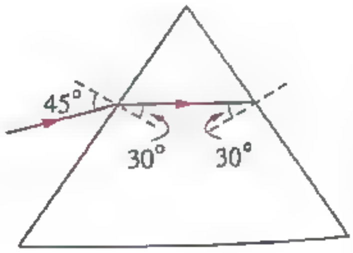



(a) A, D (b) B, C
(c) A, C (d) C, D

(13) In Young's experiment a blue light of wavelength λ is used to pass through two narrow slits that are at a distance d from each other, so interference fringes appear with a certain pattern on the observation screen that is at distance R from the slits. If the experiment is repeated under the surface of water, the distance between the fringes will ............ .

(a) remain constant
(b) decrease
(c) increase
(d) be indeterminable

(14) The opposite figure represents an equilateral triangular prism of refractive index $\sqrt{2}$, so the angle of deviation equals ........................ .




(a) 30°
(b) 45°
(c) 55°
(d) 60°

15 Light rays fall on two thin prisms, the apex angle of the first prism is 9° and its refractive index equals 1.5 and the refractive index of the second prism equals 1.75. If the angle of deviation of the light rays in the two prisms is the same, then the apex angle of the second prism equals ........................ .

(a) 6° (b) 7° (c) 8° (d) 9°

16 If the end of a spring coil is moved to make a longitudinal wave of wavelength 30 cm and periodic time 0.1 s then it is moved to make a transverse wave of periodic time 0.2 s that has the same speed as the longitudinal wave, then the wavelength of the transverse wave equals ........................ .

(a) 7.5 cm (b) 15 cm (c) 30 cm (d) 60 cm

17 If the ratio of the angle of incidence of a light ray on the interface between glass and another medium to its angle of refraction in the other medium is less than one, then ........................ .

(a) the absolute refractive index of glass is greater than the absolute refractive index of the other medium

(b) the absolute refractive index of glass is less than the absolute refractive index of the other medium

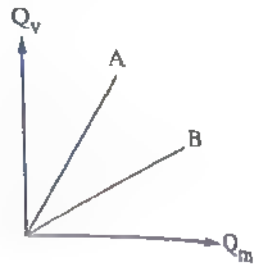
(c) the speed of light in glass is greater than the speed of the light in the other medium

(d) the wavelength of light in glass is greater than that in the medium

18 A light ray falls on one of the faces of a triangular prism with an angle of incidence $\phi$ and emerges from the opposite face with an angle of emergence $1.25\ \phi$ where the light ray deviates by an angle $0.75\ \phi$, then the ratio between the angle of deviation and the apex angle of the prism $(\frac{\alpha}{A})$ equals ........................ .

(a) $\frac{1}{4}$ (b) $\frac{1}{2}$ (c) $\frac{2}{1}$ (d) $\frac{2}{5}$

(19) The opposite graph represents the relation between the volume flow rate $(Q_v)$ and the mass flow rate $(Q_m)$ for the two liquids A and B that flow steadily inside many tubes, so the ratio between the densities of the two liquids $(\frac{\rho_A}{\rho_B})$ is .......................... .




(a) greater than one
(b) less than one
(c) equal to one
(d) indeterminable

(20) The electromagnetic waves in which the diffraction becomes ... clearer when they pass through aperture of dimensions $10^{-5}$ m are .......................... .

(a) microwaves
(b) radio waves
(c) gamma rays
(d) UV waves

(21) The critical angle between two media is given by the relation; $\sin \phi_c = \frac{n_2}{n_1}$ and this means that .......................... .

(a) $n_2 < n_1$
(b) $n_2 > n_1$
(c) $n_2 = n_1$
(d) speed of light is the same in the two media

**Second** **Answer the following questions (22 - 27)**

(22) Honey flows faster in summer than in winter, **what** is the reason for this?

..........................................................................................................................................

..........................................................................................................................................

(23) A student carried out Young's experiment to find the wavelength of a monochromatic light wave where a group of bright and dark fringes are produced on the observation screen. If the distance between the observation screen and the double-slit is 100 cm while the distance between the two slits is 0.1 mm and the distance between centers of the two successive fringes of the same type is 4.5 mm. **Calculate** the wavelength of the used light.

..........................................................................................................................................

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24. A bright object at the bottom of a lake of depth 150 cm sends light rays in all directions. If a circular light spot appeared on the surface of water, calculate the radius of this spot.
(Knowing that: Refractive index of water = 1.33)

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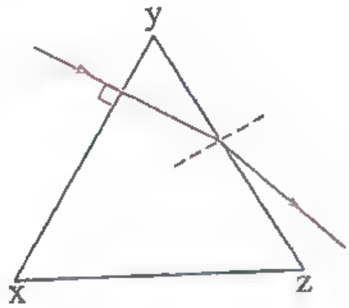


25. In the opposite figure, a monochromatic light falls from air perpendicular on an equilateral triangular prism of refractive index 1.5, then it emerges again to air. The path of the light ray in the figure is wrong. **Determine the wrong part and redraw the figure in a correct way.**

.................................................................................................................................

.................................................................................................................................

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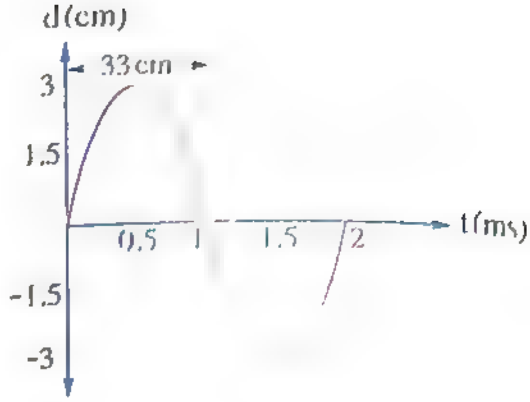
**26** A sound wave that propagates in air is producing vibrations to the air particles where the opposite graph represents the relation between the displacement(d) of one of the air particles and time (t):



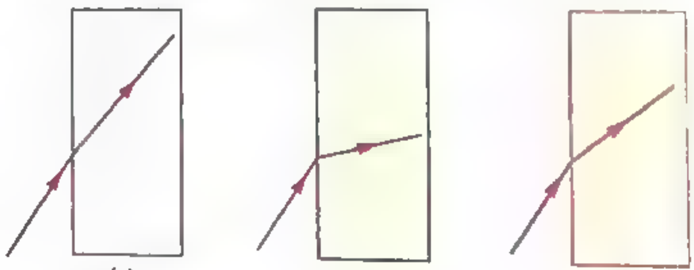

(a) **What** is the kind of the formed wave in air?

(b) **Draw** the relation between the displacement and the time with the same drawing scale of the vibration of the same air particles that transmit a sound wave of half the wavelength of the first wave and half the amplitude of the first wave.

..............................................................................................

..............................................................................................

**27** The following figures show a light ray that transfers from air into three different media. **Arrange in an ascending order** these figures according to the refractive index of each medium where the angle of incidence of the ray is the same in all cases.



(a) (b) (c)

..............................................................................................

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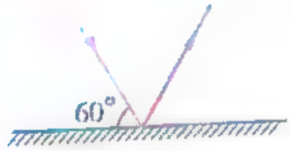
## Cumulative Exam 8

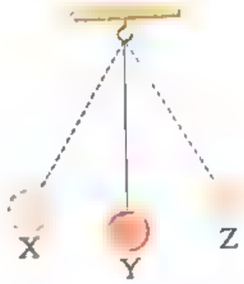
### Choose the correct answer

1. In the opposite figure, the angle of reflection of the light ray from the mirror equals ........................ .




(a) 30°   (b) 45°
(c) 60°   (d) 120°

2. During the vibration of the pendulum, the velocity of the pendulum load equals zero at the position ........... ........... .




(a) X only   (b) Y only
(c) Z only   (d) X and Z

3. In Young's experiment a yellow light source is used to form interference fringes on the observation screen. So, to make the interference fringes more distant from each other a ........................ light source should be used.

(a) green   (b) violet
(c) blue   (d) red

4. The bottom of a swimming pool may not be seen when looking at it from the air because of the ........................ of the light.

(a) interference   (b) diffraction
(c) refraction   (d) total internal reflection

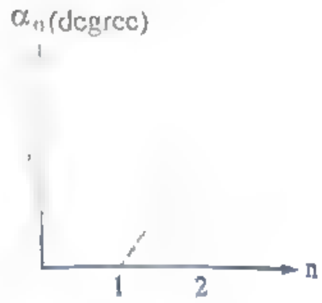
5. The ratio between the first refraction angle and the second angle of incidence in a triangular prism that is set at the minimum deviation position $\left(\frac{\theta_1}{\phi_2}\right)$ is ........................ .

(a) greater than one   (b) less than one
(c) equal to one   (d) indeterminable

If the refractive index of diamond is 2.4, then the maximum angle of incidence of a light ray that falls inside the diamond to emerge to the air equals ………………… .

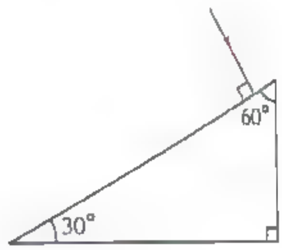
(a) 40.2° (b) 36.2° (c) 32.4° (d) 24.6°

The opposite graph shows the relation between the angles of deviation ($\alpha_0$) for several thin prisms that have the same apex angle and the refractive indices (n) of these prisms, then the apex angle of any one of them equals ………………… .




(a) 4° (b) 6°
(c) 8° (d) 10°

The opposite figure represents a light ray that falls normally on one of the faces of a triangular prism of refractive index 1.5, so its emergence angle from the prism equals ………………… .




(a) 30° (b) 41.81°
(c) 48.59° (d) 60°

A tangential force acts on a wooden plate to slide on a layer of liquid that covers the ground of a hall. If this force is doubled, then the viscosity coefficient of the liquid ………………… .

(a) decreases to its quarter (b) decreases to its half
(c) increases to the double (d) doesn't change

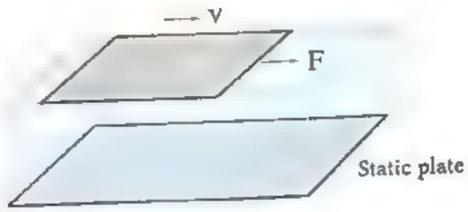
10. A horizontal rope is attached to the lower branch of a horizontal tuning fork. If the lower branch of the fork is struck, the fork produces two disturbances one in the rope and the other in air to form mechanical waves of types ………………… .

| | In the rope | In the air |
|---|---|---|
| (a) | longitudinal | transverse |
| (b) | longitudinal | longitudinal |
| (c) | transverse | transverse |
| (d) | transverse | longitudinal |

(11) A triangular prism of apex angle 45° and refractive index 1.66 is submerged in a liquid of refractive [illegible] 33. If the prism is in the minimum deviation position, the angle of deviation of [illegible] in this case equals ..................

ⓐ 9.29° 12.06° 16.19° 33.88°

(12) In the opposite figure, when liquid A is placed between the two plates and the upper plate is affected by a tangential force of 100 N, it moves with a uniform speed of 0.2 m/s and when replacing liquid A by liquid B and the upper plate is affected by a tangential force of 50 N, the plate moves with a uniform speed 0.4 m/s, then the ratio between the viscosity coefficients of the two liquids $\left(\frac{(\eta_{vs})_A}{(\eta_{vs})_B}\right)$ is ..........................

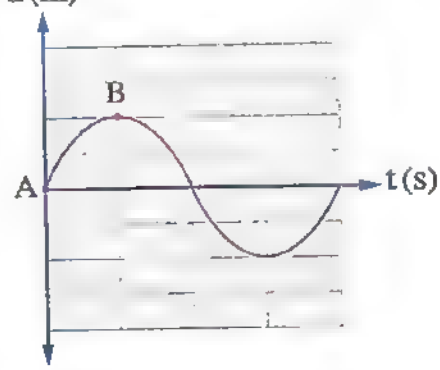



ⓐ $\frac{1}{1}$ $\frac{1}{2}$ $\frac{2}{1}$ $\frac{4}{1}$

(13) The opposite figure shows an isosceles right angle triangular prism of refractive index 1.5. If a light ray falls on one of its faces parallel to the base, it emerges from the opposite face at an angle of ..........................

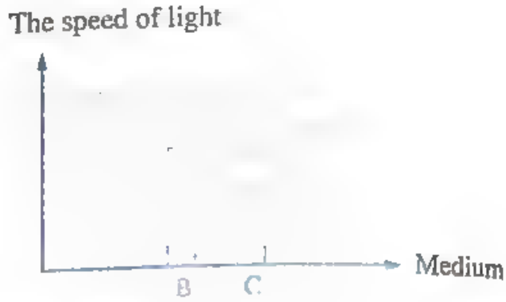
ⓐ 16.87° ⓑ 25.8°
ⓒ 28.1° ⓓ 45°

(14) The opposite graph shows the relation between the vertical displacement of the motion of a medium particle (d) and the time (t) of a wave. If the time interval between A and B is 0.15 s, then the frequency of the wave equals ..........................




ⓐ $\frac{1}{15}$ Hz ⓑ $\frac{1}{3}$ Hz
$\frac{5}{3}$ Hz ⓓ $\frac{20}{3}$ Hz

15 The opposite figure shows the speed of light in four media A, B, C, D, then the optically denser medium is ........................ .




ⓐ material A　　ⓑ material B

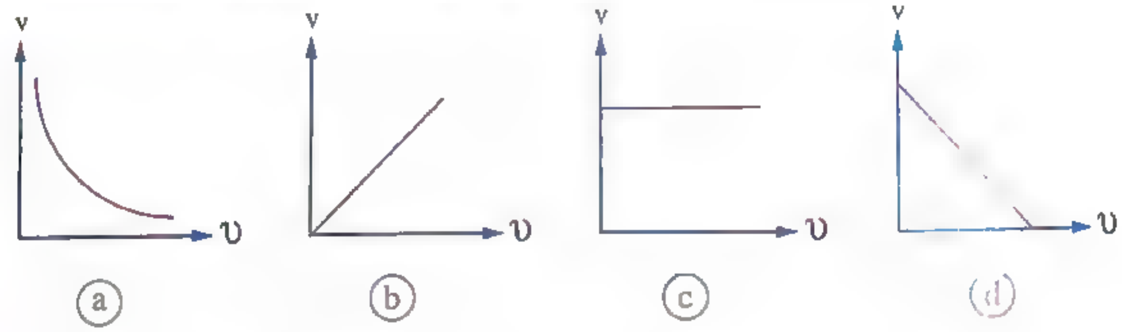
ⓒ material C　　ⓓ material D

16 The ratio between the angle of deviation of blue light in a triangular prism at minimum angle of deviation and the angle of deviation of red light respectively is ........................ .

ⓐ greater than one　　ⓑ less than one

ⓒ equal to one　　ⓓ indeterminable

17 Which of the following graphs represents the relation between the speed of propagation for different sound waves (v) in air and the frequency (υ) for each of them?




18 Three water taps were used each one separately to fill a basin. The first filled the basin in one hour, the second in $\frac{1}{2}$ an hour while the third filled it in $\frac{1}{4}$ an hour, then the time required to fill the basin when opening all taps together equals ........................ .

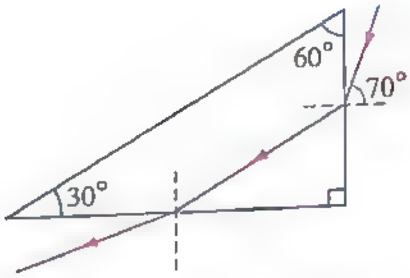
ⓐ $\frac{1}{7}$ hour　　ⓑ $\frac{3}{4}$ hour　　ⓒ $\frac{7}{9}$ hour　　ⓓ $\frac{7}{8}$ hours

19 A vibrating string makes $3 \times 10^4$ complete vibrations during one minute, so the time required to complete one vibration is ........................ .

ⓐ $2 \times 10^{-3}$ s　　ⓑ $3 \times 10^{-3}$ s

ⓒ $2 \times 10^{-2}$ s　　ⓓ $3 \times 10^{-2}$ s

(20) In the opposite figure, the apex angle of the triangular prism is ..........................



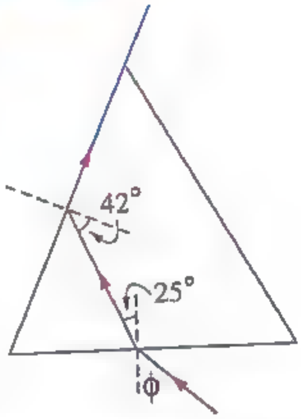

(a) 30°
(b) 60°
(c) 70°
(d) 90°

(21) A tuning fork makes 480 vibrations per second leading to produce a wave of wavelength $\lambda_1$ in air, if another tuning fork makes 120 vibrations per second which produce a wave of wavelength $\lambda_2$ in air, so $\lambda_2 =$ ..........................

(a) $\frac{\lambda_1}{4}$
(b) $\frac{\lambda_1}{2}$
(c) $2\lambda_1$
(d) $4\lambda_1$

## Second Answer the following questions (22 - 27)

(22) The opposite figure shows the path a light ray through a triangular prism. **Calculate** the value of angle ($\phi$) by which the light ray falls on one of the faces of the prism, thus it emerges from the prism tangent to the opposite face.

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(23) A wave travels between two different media (1), (2) where its wavelength in one medium is larger than its wavelength in the other medium by 10 cm. If the ratio between the speeds of the wave in the two media is $\left(\frac{v_1}{v_2} = \frac{2}{3}\right)$, **calculate** the wavelength of the wave in the medium (1).

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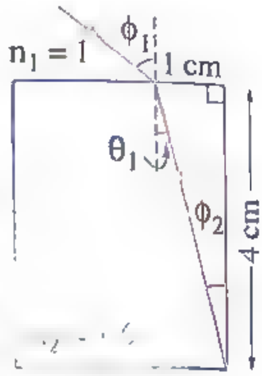
**24** From the opposite figure, **calculate** the angle of incidence of the light ray $\phi_1$.

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**25** A red laser beam is pointed toward three groups of different double-slits (A, B and C). If the separating distances between the two slits in the three groups are 0.15 mm, 0.175 mm and 0.15 mm respectively and the distances between the observation screens and the slits are 0.6 m, 0.8 m and 0.8 m respectively, **arrange in ascending order** the three groups according to the distance between the center of the central fringe and the center of the first bright fringe.

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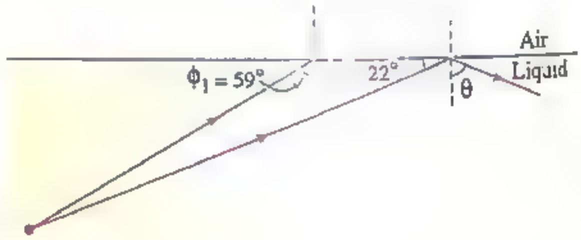
**26** The opposite figure shows light rays that fall from a liquid on the interface with air, **calculate:**

(a) The value of angle $\theta$.

(b) The absolute refractive index of the liquid.

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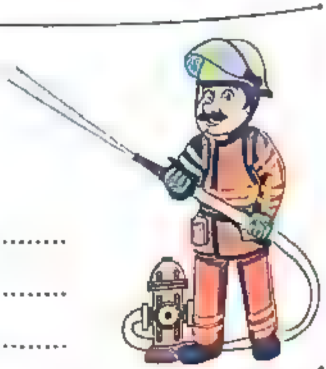
**27** **Explain why** firemen use hoses with narrow nozzles as in the opposite figure when they extinguish fires. **And what happens if** hoses of wider nozzles are used?



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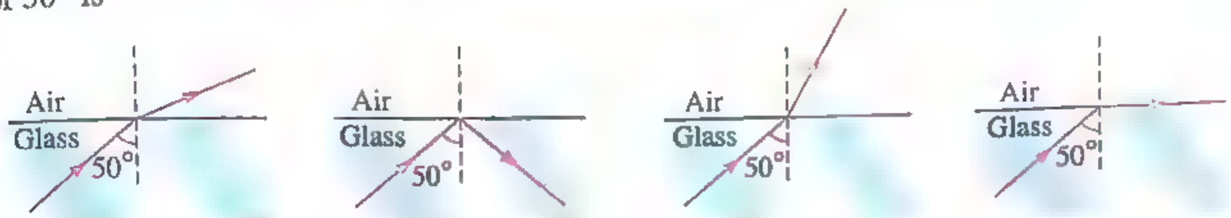
# General Exam 9

## Choose the correct answer

1. If you know that the refractive index of glass is 1.5, then the figure which shows the correct light path of the light ray which falls on the separating surface between glass and air at angle of 50° is ........................ .




ⓐ ⓑ ⓒ ⓓ

2. When light disperses into its components through a triangular prism, violet light will have greater deviation than red light because ........................

ⓐ $n_{violet} < n_{red}$
ⓑ $\lambda_{violet} < \lambda_{red}$
ⓒ $\upsilon_{violet} < \upsilon_{red}$
ⓓ $v_{red} < v_{violet}$

3. A sound wave of frequency 330 Hz propagates in cold air with a speed of 330 m/s. When it transfers to hot air, its wavelength increases by 2 %, then the wave speed in the hot air equals ........................ .

ⓐ 316.8 m/s
ⓑ 323.4 m/s
ⓒ 330 m/s
ⓓ 336.6 m/s

4. A light ray falls at an angle $\phi$ on one of the faces of a triangular prism of apex angle 75°. If the refractive index of the prism's material is $\sqrt{2}$ and the light ray emerges tangent to the opposite face of the prism, then the value of $\phi$ is ........................ .

ⓐ 0°
ⓑ 30°
ⓒ 45°
ⓓ 60°

5. A patient is injected by a needle of radius 0.3 mm, if the rate of the drug flow in cross-section of the needle is 0.5 $cm^3$/s, then the speed of the drug flow in the needle is ........................ . ($\pi$ = 3.14)

ⓐ 1.24 m/s
ⓑ 1.77 m/s
ⓒ 2.42 m/s
ⓓ 7.71 m/s

A container of thick transparent walls that have a material of refractive index 1.52. If it contains a liquid of refractive index 1.44, then the critical angle between them equals .......................

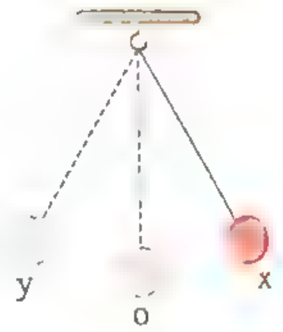
(a) 68.42° and it is located in the container medium

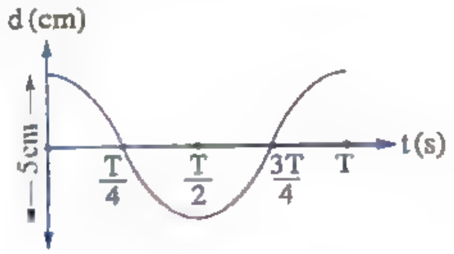
(b) 71.33° and it is located in the container medium

(c) 68.42° and it is located in the liquid

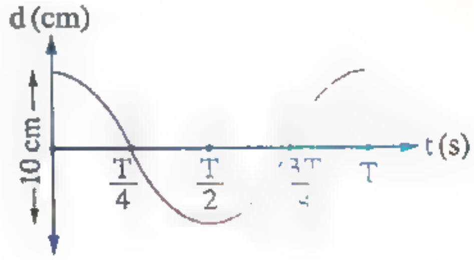
(d) 71.33° and it is located in the liquid

In the opposite figure, a simple pendulum has been displaced from its rest position (o) a distance 5 cm to position (x), then it is left to swing making a simple harmonic motion where it completes one oscillation in time T. Which the following graphs represents the relation between the displacement (d) of the pendulum away from its rest position and the time (t) during that complete oscillation starting from position x?

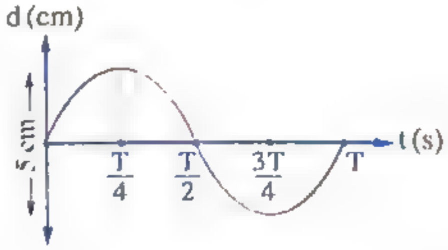


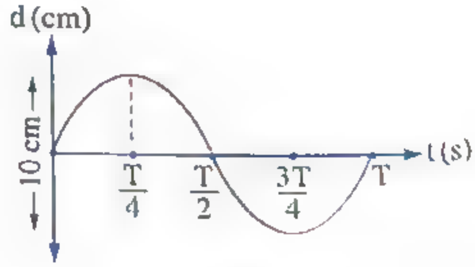

(a)




(b)




(c)



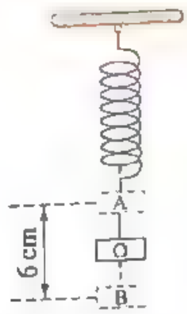

(d)

**8** In Young's experiment, if red light was used then the experiment is carried out again with blue light source, the ratio $\frac{(\Delta y)_r}{(\Delta y)_b}$ is ..................... .

(a) greater than 1 (b) less than 1

(c) equal to 1 (d) indeterminable

**9** The opposite figure shows a load that is attached to a vibrating spring, so the amplitude of the vibration equals .................... .




(a) 3 cm (b) 6 cm

(c) 9 cm (d) 12 cm

**10** Water flows steadily in a tube that is branched into several identical branches. If the diameter of the main tube is 8 times as large as the diameter of the branched tube and the speed of the water flow in the branched tube is 4 times as large as its speed in the main tube, then the number of the branched tubes is ........................ .

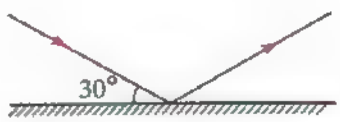
(a) 4 (b) 8 (c) 16 (d) 24

**11** Which of the following physical quantities has a measuring unit?

(a) Absolute refractive index (b) Viscosity coefficient

(c) Dispersive power (d) Relative refractive index

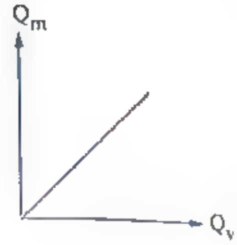
**12** From the opposite figure, the angle of reflection of the ray from the mirror equals ........................ .




(a) 30° (b) 40°

(c) 60° (d) 90°

(13) The opposite graph represents the relation between the volume flow rate ($Q_v$) and the mass flow rate ($Q_m$) for a liquid that flows steadily in many tubes, then the slope of the straight line represents ........................ .




(a) the pressure of the liquid
(b) the temperature of the liquid
(c) the speed of the liquid flow
(d) the density of the liquid

(14) The ratio between the dispersive power of a thin prism of an apex angle of [illegible] and the dispersive power of a thin prism of an apex angle 10° of the same material is ........................ .

(a) $\frac{1}{1}$ (b) $\frac{1}{2}$ (c) $\frac{2}{1}$ (d) $\frac{3}{2}$

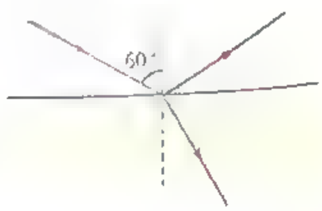
(15) If the frequency of a longitudinal wave is 50 Hz, then the required time to cover a distance equivalent to half its wavelength is ........................ .

(a) 0.08 s (b) 0.45 s (c) 0.02 s (d) 0.01 s

(16) An optical fiber that has a material of refractive index 2.1, is coated by an external layer, so the refractive index of the external layer that makes the critical angle between the two layers equal 32° is ........................ .

(a) 1.11 (b) 1.9 (c) 3.96 (d) 4.32

(17) A light beam falls from air on the surface of a transparent medium as in the opposite figure. A part of it reflects and another part refracts where the reflected and the refracted rays are perpendicular, then the critical angle of the transparent medium with the air equals ........................ .

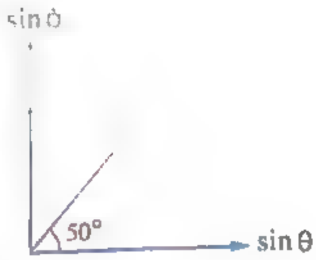



(a) 35.26° (b) 53.26° (c) 45.26° (d) 54.26°

**18** If the distance between the first crest and the z crest of a transverse wave is y, then the wavelength of the wave equals ........................ .

(a) $\frac{z-1}{y}$ (b) $\frac{y}{1}$ (c) $\frac{z}{y}$ (d) $\frac{y}{z-1}$

**19** The opposite graph represents the [illegible] of the angle of incidence (sin ϕ) and the sine of the angle of refraction (sin θ) for a light wave when it travels from air to another medium, so the speed of the wave in the medium equals ........................ .




(Knowing that: $c = 3 \times 10^8$ m/s)

(a) $2 \times 10^8$ m/s (b) $1.6 \times 10^8$ m/s (c) $2.5 \times 10^8$ m/s (d) $3 \times 10^8$ m/s

**20** By increasing the distance between the double-slit barrier and the observation screen in Young's experiment, the ........................ .

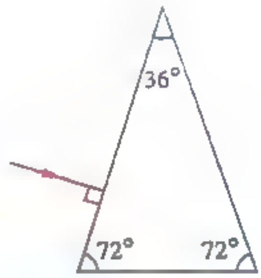
(a) fringes become more distant from each other

(b) fringes become less distant from each other

(c) distances between fringes don't change

(d) number of bright and dark fringes increases

**21** The opposite figure represents a triangular prism of refractive index 1.8 where a light ray falls on one of its faces, then the number of reflections inside the prism equals ........................ .




(a) 1 (b) 2

(c) 3 (d) 4

## Second Answer the following questions (22 : 27)

**22** "We can't observe the diffraction of light in our daily life" **Explain this sentence.**

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23 **What are the results of:**

Reducing the temperature of a liquid concerning the force affecting a solid object that moves through it?

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24 **Calculate** the ratio between the wavelengths of two waves that propagate in the same medium, if the periodic time of the first wave is half that of the second wave.

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25 A light ray falls perpendicularly on one of the faces of a triangular prism of apex angle 35° and it emerges from the prism deviated from its original path by an angle of 28°.
**Calculate** the refractive index of the prism's material for this light ray.

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26 A thin prism has refractive index for red light 1.5 and refractive index for blue light 1.55. If its apex angle is 8°, calculate:

(a) The value of its average deviation angle.

(b) The angular dispersion of the prism

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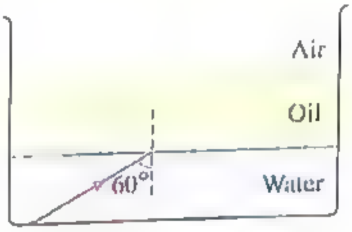
27 In the opposite figure:




A point light source is placed in the water where it produces a light ray that falls on the separating surface between the water and the oil at angle of 60°. If the refractive index of water is $\frac{4}{3}$ and the refractive index of oil is 1.8, calculate:

(a) The relative refractive index from water to oil.

(b) Will the light ray refract when it falls on the interface between oil and air?

**Explain your answer.**

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## Choose the correct answer

1. A tangential force acts on a plastic plate of area 240 $cm^2$ to slide [illegible] of 0.4 m/s on another static plate where there is a layer of liquid of thickness [illegible] between them. If the viscosity coefficient of the liquid is 2.1 $N.s/m^2$, then the tangential force that acts on the plastic plate equals ........................ .

   (a) 3 N  (b) 4 N  (c) 6 N  (d) 9 N

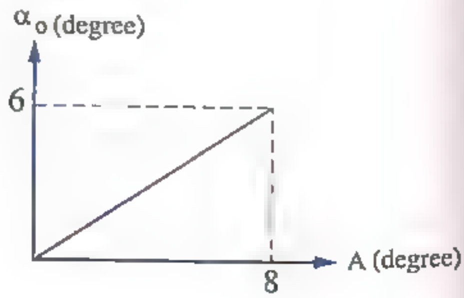
2. A monochromatic light of wavelength 6000 Å falls on a double slit. If the distance between the two slits is 0.001 m and the distance between the slits and the observation screen is 500 cm, then the distance between the fourth bright fringe and the fifth bright fringe equals ........................ .

   (a) 0.003 m  (b) 0.012 m  (c) $9 \times 10^{-4}$ m  (d) $3 \times 10^{-4}$ m

3. Two transparent media have different optical densities, the critical angle between them is 55° and the absolute refractive index of the optically rarer medium is 1.36, then the absolute refractive index of the optically denser medium is ........................ .

   (a) 1.52  (b) 1.56  (c) 1.62  (d) 1.66

4. The opposite graph shows the relation between the apex angles (A) of several thin prisms that are made of the same material and the angle of deviation ($\alpha_o$) of a light ray through each of them, so the refractive index of the prisms' material is ........................ .




   (a) 1.3  (b) 1.4
   (c) 1.5  (d) 1.75

15. A water pipe that has two different cross-sectional areas, one at the ground floor of 15 $cm^2$ and one at the upper floor of 2.5 $cm^2$. If the speed of water at the ground floor is 2 m/s, then ........................ .

| | The volume flow rate ($m^3/s$) | The speed of the water at the upper floor (m/s) |
|---|---|---|
| (a) | $10^{-3}$ | 10 |
| (b) | $10^{-3}$ | 12 |
| (c) | $3 \times 10^{-3}$ | 10 |
| (d) | $3 \times 10^{-3}$ | 12 |

16. A wave of frequency 100 Hz and wavelength 20 cm propagates in a medium, if it transfers to another medium where its speed becomes 30 m/s, then in the second medium ........................ .

| | The frequency (Hz) | The wavelength (cm) |
|---|---|---|
| (a) | 100 | 20 |
| (b) | 100 | 30 |
| (c) | 150 | 20 |
| (d) | 150 | 30 |

17. If the radius of a tube that carries a steadily flowing liquid decreases to its half, then the mass flow rate ........................ .

(a) remains constant
(b) decreases to its quarter
(c) doubles
(d) quadruples

18. A student uses in the double-slit experiment laser rays of wavelength 6328 Å. If the distance between the double slit and the observation screen is 85 cm and the distance between the centers of the central fringe and the fourth bright fringe is 1.8 mm, then the distance between the two slits is ........................ .

(a) 0.68 mm
(b) 0.8 mm
(c) 1 mm
(d) 1.2 mm

9 The opposite figure shows a light ray that falls at an angle $\phi_1$, on one of the faces of a triangular prism in the minimum deviation position.
If the refractive index of the prism's material is 1.366, then the angle of emergence and the minimum deviation angle are ........................ , ........................ respectively.


(a) 60°, 45° (b) 60°, 60° (c) 75°, 45° (d) 75°, 60°

10 If the speed of light in the two media X and Y are $2.4 \times 10^8$ m/s and $1.8 \times 10^8$ m/s respectively, then the critical angle between the two media is ........................ .

(a) 48.59° in medium X
(b) 48.59° in medium Y
(c) 53.13° in medium X
(d) 53.13° in medium Y

11 A thin prism deviates light rays with an angle of 3.6°. If the apex angle of the prism is 5°, so the refractive index of its material equals ........................ .

(a) $\sqrt{2}$ (b) 1.5 (c) 1.72 (d) 2.39

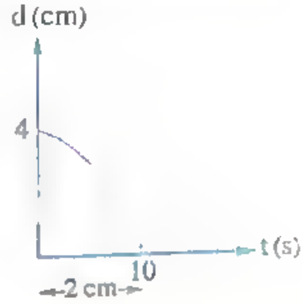
12 The interference of light becomes less noticeable in Young's experiment when ........................ .

(a) using light of very high intensity
(b) the distance between the two slits decreases
(c) the distance between the two slits increases
(d) the wavelength of the used light increases

13 If a light ray falls normal to one of the right angle faces of an isosceles triangular prism of refractive index $\sqrt{2}$, then the light ray that falls on the opposite side to the right angle will ........................ .

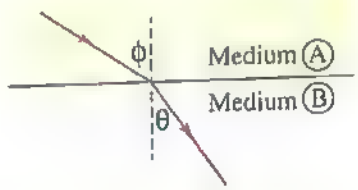
(a) emerge tangent to this face
(b) emerge by angle of emergence of 60°
(c) totally reflect
(d) emerge by angle of emergence of 70°

(14) The opposite figure represents the relation between the displacement (d) for one of the particles of a certain medium through which a wave is moving and the time (t), then the wave speed is ........................ .




ⓐ 0.2 cm/s ⓑ 0.4 cm/s
ⓒ 6 cm/s ⓓ 8 cm/s

(15) The opposite figure represents a light ray that transfers from medium (A) to medium (B), so the ratio between the speed of light in medium (A) and the speed of light in medium (B) is ........................ .




ⓐ greater than 1 ⓑ less than 1
ⓒ equal to 1 ⓓ we can't determine the answer without knowing the values of $\phi$, $\theta$

(16) In the simple pendulum, which of the following physical quantities doesn't change during the motion of the pendulum?

ⓐ Displacement ⓑ Velocity
ⓒ Potential energy ⓓ Mechanical energy

(17) The angle of deviation in the thin prism depends on all of the following except ........................ .

ⓐ the apex angle of the prism ⓑ the first angle of incidence
ⓒ the wavelength of the falling light ⓓ the type of the prism's material

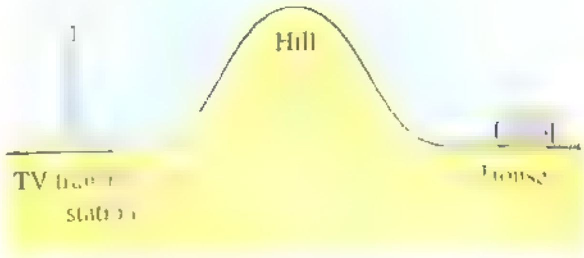
(18) When the periodic time of a wave moving in a medium increases, ........................ .

ⓐ the wavelength increases ⓑ the wavelength decreases
ⓒ the speed increases ⓓ the speed decreases

(19) A large tube of diameter 30 cm is branched into a number of narrow tubes each of radius 30 mm. If the speed of the water passing in the wide tube equals the speed of the water in the narrow tube, then the number of the narrow tubes equals ........................ .

ⓐ 25 ⓑ 50 ⓒ 75 ⓓ 100

20 The opposite figure represents a hill that separates between a TV transmission station and a house. Although the hill acts as a shield for the station but the house receives the TV station perfectly, so what happened to the TV waves at the hill?




(a) Refraction (b) Diffraction
(c) Interference (d) Reflection

21 When a light ray falls on one of the faces of an equilateral triangular prism in the position of minimum deviation, the second angle of incidence equals ........................ .

(a) 30° (b) 45° (c) 60° (d) 90°

## Second Answer the following questions (22 : 27)

22 A light ray falls on an optical fiber cable that is made of a flexible material of refractive index 1.65. **Calculate** the least angle of incidence of the light ray that falls on the internal surface of the cable to undergo total internal reflection.

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23 A light ray falls on an optical fiber cable that is made of a flexible material of refractive index 1.65. **Calculate** the least angle of incidence of the light ray that falls on the internal surface of the cable to undergo total internal reflection.

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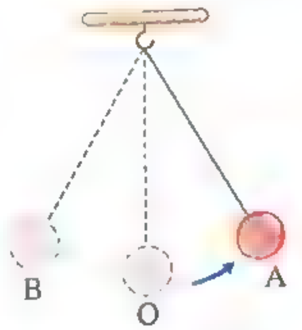
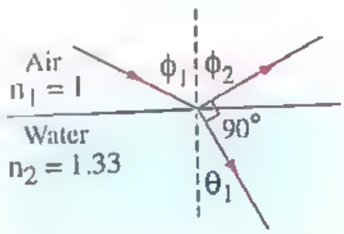
24 From your study, what is the advice that you can give to the drivers to save fuel on roads?

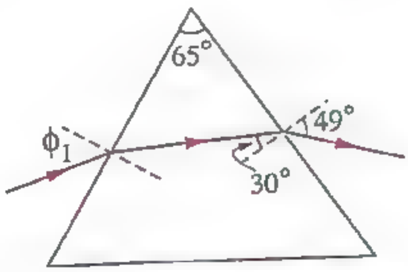
25 Asimple pendulum is displaced from its original position, then it is left to swing with a simple harmonic motion, **at which position**, the speed of the pendulum's bob becomes maximum?




26 From the opposite figure, calculate the value of angles $\phi_1$ and $\theta_1$.
(Knowing that: $\sin(90 - \theta) = \cos\theta$)




27 The opposite figure shows the path of a light ray that falls on one of the faces of a triangular prism, **calculate:**
(a) The refractive index of the prism's material.
(b) The angle of deviation of the light ray.



# PHYSICS

GUIDE ANSWERS

FIRST TERM

2nd SEC.
2023

# CONTENTS

# First | Answers of the Book Questions

# Answers of Unit One

## Chapter 1 Lesson One

### First Multiple choice questions

1. ⓐ a periodic motion
2. ⓒ an oscillatory motion
3. ⓓ $x \rightarrow y \rightarrow z \rightarrow y \rightarrow x$
4. ⓑ double the distance BC

$\because$ The distance covered in a complete oscillation = 4 × The distance of the amplitude

$\therefore$ The distance covered in a complete oscillation is four times the distance AB or AC and double the distance BC

$\therefore$ The correct choice is ⓑ.

5. ⓐ A
6. ⓓ $\frac{1}{4}$
7. ⓐ
8. ⓐ $\frac{T}{4}$
9. ⓑ at the maximum displacement away from the equilibrium position
10. ⓒ 1.25 Hz, 0.8 s

$\upsilon = \frac{N}{t} = \frac{75}{60} = 1.25$ Hz

$T = \frac{t}{N} = \frac{60}{75} = 0.8$ s

Or

$T = \frac{1}{\upsilon} = \frac{1}{1.25} = 0.8$ s

11. ⓒ 1000

$T = \frac{t}{N}$

$N = \frac{t}{T} = \frac{100}{0.1} = 1000$

12. ⓑ 20 Hz

$\text{Slope} = \frac{\Delta N}{\Delta t} = \frac{800-0}{40-0} = 20\ s^{-1}$

$\because \upsilon = \frac{N}{t}$

$\therefore \upsilon = \text{Slope} = 20$ Hz

13. ⓓ
14. ⓓ
15. ⓒ $\frac{4}{1}$

$\because \upsilon = \frac{1}{T}$

$\therefore \frac{\upsilon_x}{\upsilon_y} = \frac{T_y}{T_x} = \frac{4}{1}$

16. ⓐ 0.5 Hz

When the bob of the pendulum moves from point X to point Y, it makes half a complete oscillation.

$\therefore \upsilon = \frac{N}{t} = \frac{0.5}{1} = 0.5$ Hz

17. ⓑ 25 Hz

$T = 4 \times$ Time of amplitude

$= 4 \times 0.01 = 0.04$ s

$\upsilon = \frac{1}{T} = \frac{1}{0.04} = 25$ Hz

18. ⓓ 625

$T = \frac{t}{N}$ , $\upsilon = \frac{N}{t}$

$\therefore \frac{T}{\upsilon} = \frac{t^2}{N^2} = \frac{1}{625}$

$\frac{(25)^2}{N^2} = \frac{1}{625}$

$\therefore N = 625$

19. (i) ⓑ 0.04 s

$T = 4 \times 0.01 = 0.04$ s

(ii) ⓐ 3 cm

$A = 0.5 \times 6 = 3$ cm

(iii) ⓑ 300 cm/s

$\bar{v} = \frac{d}{t} = \frac{6}{\frac{0.04}{2}} = 300$ cm/s

20. ⓒ
21. (i) ⓑ point + X

(ii) ⓐ point – X

(iii) ⓑ point O

22. ⓐ half the periodic time
23. (i) ⓒ 10 cm

(ii) ⓒ 4 s

24. ⓐ At the beginning of observing the motion of the pendulum bob, its displacement from point x is equal to zero, then the displacement increases when it moves towards point y till reaching a maximum value at point y, then decreases when it returns from point y to point x until it reaches zero when the bob of the pendulum reaches point x again, then the value of the displacement increases but in the opposite direction until it reaches a maximum value at point z.

$\therefore$ The correct choice is ⓐ.

25 ⓑ

26 (i) ⓒ 31

(ii) ⓒ 60

(iii) ⓑ 30

27 ⓓ constant at all points

28 (i) ⓑ 2 cm

The maximum displacement for the bob of the pendulum from position x represents double the amplitude.

$\therefore A = \frac{d}{2} = \frac{4}{2} = 2$ cm

(ii) ⓑ 0.5 Hz

The time taken by the pendulum from position x until it returns back to position x again = The periodic time

$\therefore \upsilon = \frac{1}{T} = \frac{1}{2} = 0.5$ Hz

29 ⓓ z, 0.5 m/s towards the right

30 ⓒ $t_1 < t_2$

When the bob of the pendulum moves away from its equilibrium position, its velocity decreases gradually, hence the time taken to move from position x to position y ($t_1$) is less than the time taken to move from position y to position z ($t_2$).

31 ⓐ y

32 (i) ⓑ 1 s

The bob has a maximum displacement in the negative direction for the first time when it makes half a complete oscillation that is after the half of a periodic time passes.

$\therefore t = \frac{T}{2} = \frac{2}{2} = 1$ s

(ii) ⓐ 0.5 s

The bob has a maximum speed for the first time when it passes by point o after a quarter of a complete oscillation that is after the quarter of a periodic time passes.

$\therefore t = \frac{T}{4} = \frac{2}{4} = 0.5$ s

33 ⓐ its equilibrium position

34 ⓑ point O

35 ⓑ y to z

36 ⓓ

At the maximum displacement made by the pendulum bob from its equilibrium position, the velocity of the body is equal to zero and also its kinetic energy and when it moves from this position to its equilibrium position, its velocity increases and also its kinetic energy until it reaches to its maximum value at the equilibrium position then it decreases again until it reaches zero at the maximum displacement.

37 ⓐ 1 > 2 > 3

When a body moves with a greater displacement, it stores a greater potential energy, this energy is converted into kinetic energy during the body motion and therefore the body that has the greater displacement has the greater kinetic energy.

∴ The correct choice is ⓐ.

## Second Essay questions

1 The periodic time decreases to one third of its initial value because frequency is inversely proportional to periodic time according to the relation ($T = \frac{1}{\upsilon}$).

2 **Answer by yourself.**

3 Slope $= \tan\theta = \frac{\Delta\upsilon}{\Delta(\frac{1}{T})}$

$\because \upsilon = \frac{1}{T}$

$\therefore \tan\theta = 1$ $\qquad$ $\therefore \theta = 45°$

4 (a) The string reaches the maximum speed at point b.

(b) The string has the maximum potential energy at points a and c.

(c) $\frac{t_{bc}}{t_{ba}} = \frac{1}{1}$

5 * The amplitude increases by increasing the displacement of the body from its equilibrium position ($d_2 > d_1$).

* By increasing the vertical height of the pendulum bob from its equilibrium position, the maximum potential and kinetic energies increase and therefore the mechanical energy of the pendulum increases.

**6** (a) at : t = 0, 4 s, 8 s (b) at : t = 2 s, 6 s
(c) at : t = 1 s, 3 s, 5 s, 7 s

## Answers of New Types of questions

### First Choose two correct answers

**1** ⓐ The elastic potential energy of the load.
ⓑ The displacement of the load away from its equilibrium position.

**2** ⓐ The amplitude gets doubled.
ⓒ The speed of the body at its original position becomes greater.

### Second Put in front of each of the following sentences the suitable number of the curve shown in the graph

ⓐ ③ ⓑ ① ⓒ ②

## Chapter 1 Lesson Two

### First Multiple choice questions

**1** ⓒ energy

**2** ⓓ U, Q
The waves propagate on water surface as concentric circles whose center is the wave source.
∴ The correct choice is ⓓ.

**3** ⓒ all directions with the same speed

**4** ⓑ Up and down.

**5** ⓑ B **6** ⓓ b, d

**7** ⓓ $\frac{1}{200}$ s

$T = \frac{1}{\upsilon} = \frac{1}{50}$ s

$t_{xy} = \frac{T}{4} = \frac{\frac{1}{50}}{4} = \frac{1}{200}$ s

**8** (i) ⓐ 2 cm (ii) ⓑ 125 Hz

**9** ⓐ 45 Hz

$N = 10 - 1 = 9$

$\upsilon = \frac{N}{t} = \frac{9}{0.2} = 45$ Hz

**10** ⓒ 12, 1.8

**11** ⓓ Q, Q

* From the figure, the wave that has the largest amplitude is wave Q

$\because \lambda = \frac{x}{N}$

At constant x:

$\therefore \lambda \propto \frac{1}{N}$

$\because N_Q > N_P$

$\therefore \lambda_Q < \lambda_P$

$\because v = \lambda \upsilon$

∵ The two waves have the same speed.

$\therefore \lambda \propto \frac{1}{\upsilon}$

$\because \lambda_Q < \lambda_P$

$\therefore \upsilon_Q > \upsilon_P$

∴ The correct choice is ⓓ.

**12** (i) ⓒ c decreases to its half

∵ The frequency is doubled.

$\because \lambda \propto \frac{1}{\upsilon}$

∴ The wavelength decreases to its half.

∴ c and b decrease to their half.

∴ The correct choice is ⓒ.

(ii) ⓓ e increases to the double

When the amplitude of the wave is doubled, the maximum displacement of the medium particles from the equilibrium position increases.

∴ e and a increase to the double.

∴ The correct choice is ⓓ.

**13** ⓒ T

**14** ⓒ $(n - 1)\lambda$

$\lambda = \frac{x}{N}$

$x = N\lambda$

$\because N = n - 1$

$\therefore x = (n - 1)\lambda$

**15** ⓒ 40 cm **16** ⓓ Downward.

**17** ⓑ Horn speaker

**18** ⓓ A region of low density which is called rarefaction.

**19** ⓒ 0.5 m **20** ⓑ

**21** ⓐ PQ **22** ⓐ halved

**23** (i) ⓑ $\frac{2}{1}$ (ii) ⓒ $\frac{1}{2}$

**24** ⓒ 20 cm **25** ⓐ longitudinal waves

26 ⓓ transverse wave of wavelength y

27 ⓑ They require a medium in order to propagate.

28 ⓐ could be transverse or longitudinal of amplitude 2 cm

29 ⓑ 10 Hz

From the graphs, we can see that the wave has moved a quarter of a wavelength through 0.025 s.

$\therefore \upsilon = \frac{N}{t} = \frac{0.25}{0.025} = 10 \text{ Hz}$

30 ⓑ Their speed in a medium equals the product of their frequency and wavelength.

31 ⓒ

32 ⓐ remains constant

33 ⓑ 100 Hz

$\upsilon = \frac{v}{\lambda} = \frac{300}{3} = 100 \text{ Hz}$

34 (i) ⓑ 50 m/s

$v = \lambda\upsilon = 0.5 \times 100 = 50 \text{ m/s}$

(ii) ⓑ 0.17 m

$\lambda = \frac{v}{\upsilon} = \frac{50}{300} = 0.17 \text{ m}$

35 ⓓ 1 m/s

36 ⓐ its wavelength increases to the double

37 ⓒ 6.4 m/s

38 ⓐ 10 cm

* From the graph:

$\lambda = \frac{x}{N} = \frac{90}{2.25} = 40 \text{ cm}$

* When a particle of the medium moves 4 cm from its equilibrium position, it makes a quarter wave.

$\therefore x = \frac{\lambda}{4} = \frac{40}{4} = 10 \text{ cm}$

39 (i) ⓐ 9 cm

$A = \frac{18}{2} = 9 \text{ cm}$

(ii) ⓑ 2.5 Hz

$T = 0.4 \text{ s}$

$\upsilon = \frac{1}{T} = \frac{1}{0.4} = 2.5 \text{ Hz}$

(iii) ⓒ 20 cm

$\lambda = \frac{x}{N} = \frac{35}{1.75} = 20 \text{ cm}$

(iv) ⓐ 0.5 m/s

We can calculate the speed of wave propagation by two methods:

- The first method:

$v = \lambda\upsilon = 20 \times 10^{-2} \times 2.5 = 0.5 \text{ m/s}$

- The second method:

$v = \frac{x}{t} = \frac{35 \times 10^{-2}}{0.7} = 0.5 \text{ m/s}$

40 ⓓ

41 ⓓ 333 m/s

$v = \text{Slope} = \frac{\Delta\upsilon}{\Delta\left(\frac{1}{\lambda}\right)} = \frac{250 - 0}{0.75 - 0} = 333 \text{ m/s}$

42 ⓐ $\upsilon_A > \upsilon_B$

43 ⓒ speed

44 ⓒ $2\lambda$, c

45 ⓒ 0.017 m, 17 m

$\lambda_{\text{shortest}} = \frac{v}{\upsilon_{\text{highest}}} = \frac{340}{2 \times 10^4} = 0.017 \text{ m}$

$\lambda_{\text{longest}} = \frac{v}{\upsilon_{\text{lowest}}} = \frac{340}{20} = 17 \text{ m}$

46 ⓑ 4 m/s

$\upsilon = \frac{N}{t} = \frac{50}{5} = 10 \text{ Hz}$

$N = 4 - 1 = 3$

$\lambda = \frac{x}{N} = \frac{120 \times 10^{-2}}{3} = 0.4 \text{ m}$

$v = \lambda\upsilon = 0.4 \times 10 = 4 \text{ m/s}$

47 ⓒ 0.3 m

$\lambda = \frac{v}{\upsilon} = \frac{0.4}{4} = 0.1 \text{ m}$

$N = 5 - 2 = 3$

$\lambda = \frac{x}{N}$

$x = \lambda N = 0.1 \times 3 = 0.3 \text{ m}$

48 ⓓ $\frac{2\lambda}{v}$

49 ⓓ 1200 waves

$\upsilon = \frac{N}{t} = \frac{30}{1} = 30 \text{ Hz}$

$\lambda = \frac{v}{\upsilon} = \frac{1.5}{30} = 0.05 \text{ m}$

$N = \frac{x}{\lambda} = \frac{60}{0.05} = 1200 \text{ waves}$

50 ⓐ

$\because$ The propagating wave is the same wave.

$\therefore$ The frequency of the wave is constant.

$\because v = \lambda\upsilon$ $\quad\therefore v \propto \lambda$

$\therefore$ The wave which has the longest wavelength is the wave with the highest speed.

$\therefore$ The correct choice is ⓐ.

51 ⓐ $\frac{9}{4}$

$\because \lambda = \frac{x}{N}$

$\frac{\lambda_x}{\lambda_y} = \frac{\ell}{2} \times \frac{4.5}{\ell} = \frac{9}{4}$

$\because$ The frequency of the wave is constant.

$\because v = \lambda\upsilon$ $\quad\therefore v \propto \lambda$

$\frac{v_x}{v_y} = \frac{\lambda_x}{\lambda_y} = \frac{9}{4}$

52 (d) 60 cm

53 (i) (c) 4 m

$N = 7 - 2 = 5$

$\lambda = \frac{x}{N} = \frac{20}{5} = 4$ m

(ii) (b) 160 m/s

$N = 5 - 1 = 4$

$\upsilon = \frac{N}{t} = \frac{4}{0.1} = 40$ Hz

$v = \lambda\upsilon = 4 \times 40 = 160$ m/s

54 (i) ⓐ 0.04 m

$\lambda = \frac{x}{N} = \frac{2}{50} = 0.04$ m

(ii) ⓑ 10 Hz

$\upsilon = \frac{N}{t} = \frac{50}{5} = 10$ Hz

(iii) ⓓ 0.4 m/s

$v = \lambda\upsilon = 0.04 \times 10 = 0.4$ m/s

55 ⓐ 1.1 m

$v = \frac{x}{t} = \frac{0.99 \times 10^3}{3} = 330$ m/s

$\lambda = \frac{v}{\upsilon} = \frac{330}{300} = 1.1$ m

56 ⓓ 320 m/s

$N = 6 - 1 = 5$

$\lambda = \frac{x}{N} = \frac{8}{5} = 1.6$ m

$v = \lambda\upsilon = 1.6 \times 200 = 320$ m/s

57 ⓑ The frequency $\upsilon_1$ remains constant and the wavelength becomes $\frac{2}{3}\lambda_1$

* When a wave travelled from medium to another, its frequency remains constant.

$\because v = \lambda\upsilon$

$\therefore v \propto \lambda$

$\therefore \frac{v_1}{v_2} = \frac{\lambda_1}{\lambda_2}$

$\frac{v_1}{\frac{2}{3}v_1} = \frac{\lambda_1}{\lambda_2}$

$\lambda_2 = \frac{2}{3}\lambda_1$

$\therefore$ The correct choice is (b).

58 (i) ⓑ $\frac{1}{1}$

$\because$ The two waves propagate in the same medium.

$\therefore$ They have the same speed.

$\frac{v_a}{v_b} = \frac{1}{1}$

(ii) (b) $\frac{1}{2}$

$\lambda \propto \frac{1}{\upsilon}$

$\frac{\lambda_a}{\lambda_b} = \frac{\upsilon_b}{\upsilon_a} = \frac{256}{512} = \frac{1}{2}$

59 ⓒ $\frac{1}{1}$

When the wave travelled from medium to another, its wavelength and speed change while its frequency remains constant.

$\therefore \frac{\upsilon_1}{\upsilon_2} = \frac{1}{1}$

60 ⓒ 512 Hz

61 ⓐ $4.5 \times 10^6$ m

$x = v\frac{t}{2} = 3 \times 10^8 \times \frac{0.03}{2} = 4.5 \times 10^6$ m

62 ⓑ 2.5 m/s

$\because$ The time of $\frac{1}{4}$ wave = 2 s

$\therefore T = 4 \times 2 = 8$ s

$\upsilon = \frac{1}{T} = \frac{1}{8} = 0.125$ Hz

$\lambda = 20$ m

$v = \lambda\upsilon = 20 \times 0.125 = 2.5$ m/s

63 ⓐ $\frac{4}{3}$

$v_{wave} = \frac{x}{t} = \frac{12}{0.3} = 40$ cm/ms

$v_{particles} = \frac{\text{Amplitude}}{\frac{1}{4}T} = \frac{3}{\frac{1}{4} \times 0.4} = 30$ cm/ms

$\therefore \frac{v_{wave}}{v_{particles}} = \frac{40}{30} = \frac{4}{3}$

64 ⓓ 2 m

$\because$ The tuning forks vibrate in air.

$\therefore v_1 = v_2$

$\upsilon_1\lambda_1 = \upsilon_2\lambda_2$

$850 \times 0.4 = 170$ X

$\therefore$ X = 2 m

65 ⓓ 0.05 m

$\because 2A = \frac{\lambda}{2}$ $\qquad \therefore \lambda = 4A$

$v = \upsilon\lambda$

$3.2 = 16 \times 4A$

$\therefore A = 0.05$ m

66 ⓒ 340 m/s

$\frac{\upsilon_1}{\upsilon_2} = \frac{\lambda_2}{\lambda_1}$

$\frac{680}{425} = \frac{\lambda_1 + 0.3}{\lambda_1}$

$680\,\lambda_1 = 425\,\lambda_1 + 127.5$

$\lambda_1 = 0.5$ m

$\therefore v = \lambda_1 \upsilon_1 = 0.5 \times 680 = 340$ m/s

67 ⓑ 2.65 km

$\because v = \frac{d}{t}$

$t_{air} - t_{water} = \frac{d}{v_{air}} - \frac{d}{v_{water}}$

$6 = d\left(\frac{1}{340} - \frac{1}{1480}\right)$

$\therefore d = 2648.42$ m $= 2.65$ km

68 ⓓ 320 m/s

$\because v = \frac{d}{t}$

$t_{sound} - t_{light} = \frac{d}{v} - \frac{d}{c} = d\left(\frac{1}{v} - \frac{1}{c}\right)$

$18.74998 = 6 \times 10^3 \times \left(\frac{1}{v} - \frac{1}{3 \times 10^8}\right)$

$\therefore v = 320$ m/s

69 ⓒ

When a wave travels from medium to another, its frequency remains constant and also its periodic time (2 s) and according to the relation ($v = \lambda\upsilon$), when its speed increases to double, its wavelength increases to double.

$\therefore$ The correct choice is ⓒ.

70 ⓐ 22.5 m/s

$\because$ The wavelength is the distance between the centers of two successive compressions or rarefactions.

$\therefore$ The distance between the centers of a compression and a successive rarefaction = Half the wavelength

$\lambda = 2 \times 0.15 = 0.3$ m

$T = 2 \times \frac{1}{150} = \frac{1}{75}$ s

$\upsilon = \frac{1}{T} = \frac{1}{\frac{1}{75}} = 75$ Hz

$v = \lambda\upsilon$

$= 0.3 \times 75$

$= 22.5$ m/s

## Second Essay questions

1 (a) Longitudinal wave.

(b) The direction of particles' vibrations is along the line of wave propagation.

2 Because light is electromagnetic waves and sound is mechanical waves and the speed of the electromagnetic waves is far much higher than the speed of mechanical waves.

3 We can hear the sound of the alarm clock in jar (1) and we cannot hear the alarm in jar (2) because sound is a mechanical wave which needs a medium (like air) to propagate through it and it doesn't propagate through vacuum.

4 (1) Because electromagnetic waves consist of two perpendicular fields, electrical and magnetic, and neither of them needs a medium to propagate through it.

(2) Because light is an electromagnetic wave which can travel in empty space and sound is a mechanical wave that doesn't travel in space.

(3) Because sound is a mechanical wave which needs a medium through which it can travel and the Moon doesn't have an atmosphere, so they use electromagnetic wireless devices to communicate.

5 (a) Doesn't change. (b) Decreases.

(c) Increases. (d) Decreases.

(e) Doesn't change.

6 (a) They travel at the same speed because sound travels at constant speed in air.

(b) The frequency of the girl's sound is higher than that of the man's sound because the wavelength of the girl's sound is smaller than that of the man's sound ($\upsilon \propto \frac{1}{\lambda}$).

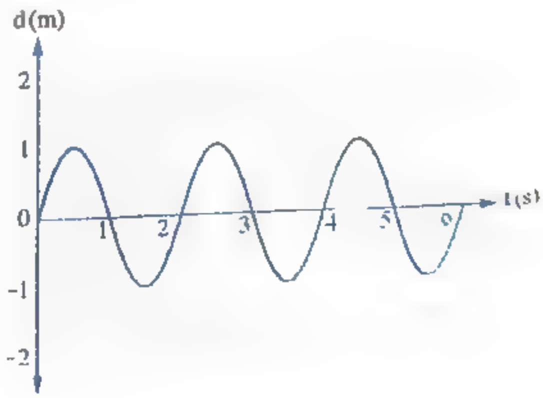
7 (a) $3 > 2 = 1$

(b) $1 = 2 > 3$

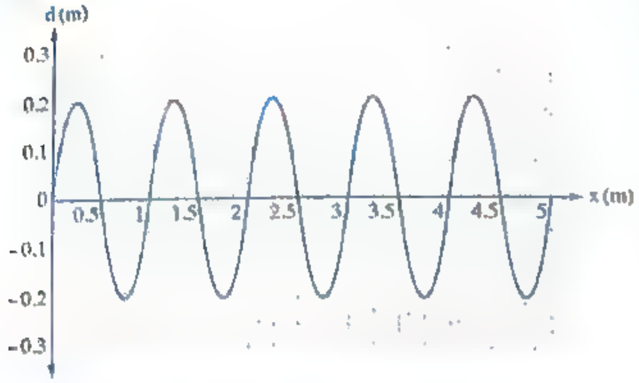
8 (a) Mechanical transverse wave.

(b) $\upsilon = \frac{1}{T} = \frac{1}{4} = 0.25$ Hz

(c)



**9**




## Answers of New Types of questions

### First Choose two correct answers

**1** ⓑ Its frequency is 37.5 Hz and its speed of propagation is 4.5 m/s.

ⓔ Its periodic time is $\frac{2}{75}$ s and its wavelength is 12 cm.

**2** ⓒ The double of distance S represents the wavelength.

ⓔ Distance P represents the double of the wave amplitude.

### Second Put in front of each of the following sentences the suitable number of the wave that represents it

(1) Wave ①

(2) Wave ①

(3) Wave ②

(4) Wave ②

## Answers of Test on Chapter 1

### First Choose the correct answer

**1** ⓒ 3, 1.25

**2** ⓑ 120 Hz

**3** ⓒ 340

**4** ⓑ 1386 m/s

**5** ⓓ

**6** ⓐ $T_A > T_B$

**7** ⓒ 20 cm

**8** ⓑ 0.5 m

**9** ⓑ $\frac{1}{1}$

**10** ⓑ 0.1 m/s

### Second Answer the following questions

**11** The pendulum starts with maximum potential energy and zero kinetic energy, then its potential energy decreases and its kinetic energy increases until it reaches the equilibrium position where its potential energy becomes zero and its kinetic energy becomes maximum value.

**12** The wavelength will be decreased by 33.33 %.

**13** $v = \frac{d}{t} = \frac{45}{0.02} = 2250$ m/s

**14** Wavelength would increase by 20 %.

**15** $\upsilon = \frac{30}{60} = 0.5$ Hz

$T = \frac{60}{30} = 2$ s

**16** Since sound propagates in air as longitudinal waves, the molecules of air inside the tube move back and forth along the direction of wave propagation forming regions of consecutive compressions and rarefactions along the length inside the tube, this type of wave motion can be explained with considering the vibrational motion of prong of the fork and how this motion affects the adjacent air molecules of the prong.

**17** $T = \frac{t}{N} = \frac{25 \times 10^{-3}}{1.5} = 16.667 \times 10^{-3}$ s

$\lambda = \frac{x}{N} = \frac{540 \times 10^{-2}}{0.75} = 7.2$ m

$v = \frac{\lambda}{T} = \frac{7.2}{16.667 \times 10^{-3}} = 432$ m/s

(Or) $v = \frac{2 \times 540 \times 10^{-2}}{25 \times 10^{-3}} = 432$ m/s

# Chapter 2 Lesson One

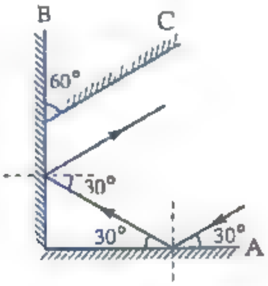
## First Multiple choice questions

1. (b) Y < Z < M
2. (a) 40°
3. (b) v
4. (a) 0°
5. (c) 180°

When a light ray falls perpendicular to the surface of a plane mirror, it gets reflected on itself i.e., the ray changes its path by an angle of 180°.

6. (d)
7. (d) The ray is reflected parallel to mirror C.

Applying the laws of light reflection and according to the geometry of the figure:

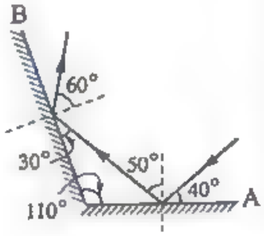



∴ The correct choice is (d).

8. (c) 60

Applying the laws of light reflection and according to the geometry of the figure:

∴ The correct choice is (c).




9. (b) 42°

∵ The mirror moved in clockwise direction.

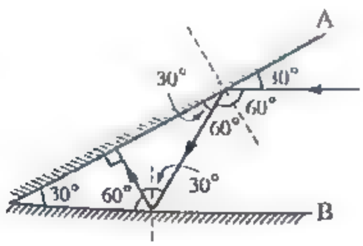
∴ The normal to the mirror surface moved closer to the incident ray with 18°.

∴ $\phi_1 = 60 - 18 = 42°$

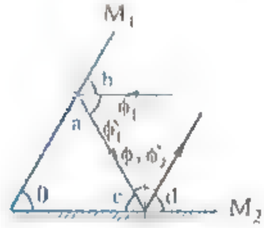
∴ $\phi_1 = \phi_2 = 42°$

10. (i) (c) 30° (ii) (d) 0°

Applying the laws of light reflection and according to the geometry of the figure :




11. (c) 60°




- Applying the laws of reflection :

$\hat{a} = \hat{b}$ , $\hat{c} = \hat{d}$ (1)

- By alternate angles theorem:

$\hat{\theta} = \hat{b}$ , $\hat{\theta} = \hat{d}$ (2)

From (1) and (2) :

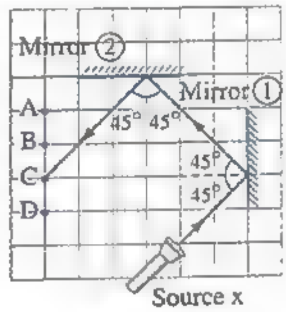
$\hat{\theta} = \hat{a} = \hat{c}$

∴ The triangle is isosceles.

∴ $\theta = 60°$

12. (c) C

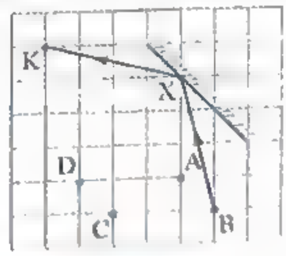
Applying the laws of light reflection :




∴ The correct choice is (c).

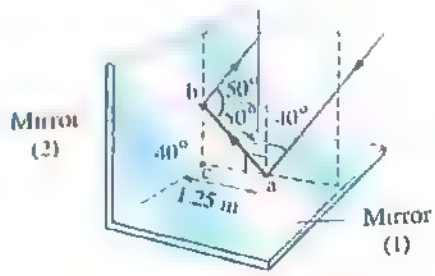
13. (b) source B

Ray KX represents the reflected ray, then by applying the laws of light reflection :




∴ The correct choice is (b).

14.



(i) ⓑ 50°

(ii) ⓒ 1.94 m

• In triangle abc :

- Side ac (that is adjacent to the angle of 50°) equals 1.25 m.
- Side ab (the hypotenuse) represents the distance covered by the ray from the point of its reflection from mirror (1) till getting incident on mirror (2).

$\therefore \cos 50 = \frac{\text{Adjacent}}{\text{Hypotenuse}} = \frac{ac}{ab} = \frac{1.25}{ab}$

$\therefore ab = 1.94$ m

15 ⓓ the speed of light

16 ⓒ The direction of propagation

17 ⓐ constant for the two media

18 ⓓ angle 2, angle 4

19 ⓒ remains constant

20 ⓐ

21 ⓒ

22 ⓑ less than 60°

23 ⓓ 38°, 52.88°

24 ⓐ 30°

25 ⓑ $\sqrt{3}$

26 ⓓ 1.22

27 ⓒ 1.45

$\because$ The light ray travels from an optically rarer medium to an optically denser medium.

$\therefore$ The light ray gets refracted towards the normal.

$n = \frac{\sin \phi}{\sin \theta} = \frac{\sin 52}{\sin (52 - 19)} = 1.45$

28 ⓑ 1.1

29 ⓐ 24.29°

$\phi = 90 - 50 = 40°$ , $n = \frac{\sin \phi}{\sin \theta} = \frac{c}{v}$

$\frac{\sin 40}{\sin \theta} = \frac{3 \times 10^8}{1.92 \times 10^8}$ , $\therefore \theta = 24.29°$

30 (i) ⓐ 1.5

$\text{Slope} = \frac{\Delta \sin \phi}{\Delta \sin \theta} = \frac{0.6 - 0}{0.4 - 0} = 1.5$

$\because {}_1n_2 = \frac{\sin \phi}{\sin \theta}$ $\therefore {}_1n_2 = \text{Slope} = 1.5$

(ii) ⓓ $1.33 \times 10^8$ m/s

${}_1n_2 = \frac{v_1}{v_2}$ , $v_2 = \frac{v_1}{{}_1n_2} = \frac{2 \times 10^8}{1.5} = 1.33 \times 10^8$ m/s

31 ⓑ $\upsilon$ , $\frac{\lambda}{n}$

32 ⓓ 4667 Å

33 ⓐ $2.25 \times 10^8$ m/s

$n = \frac{c}{v} = \frac{\lambda_{air}}{\lambda_{water}}$ , $\frac{3 \times 10^8}{v} = \frac{700}{526}$

$v = 2.25 \times 10^8$ m/s

34 ⓑ $\frac{1}{2}$

35 ⓑ decreases, toward the normal line

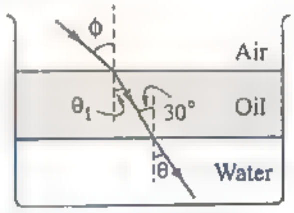
36 ⓐ 37°

37 ⓒ 33.69°

38 ⓑ angle β

39 ⓓ 1.5

40 ⓒ 47.73°, 33.81°




- From the geometry of the figure :

$\theta_1 = 30°$ (alternate angles)

- When the ray travels from air to oil :

$n_{oil} = \frac{\sin \phi_1}{\sin \theta_1}$ , $1.48 = \frac{\sin \phi}{\sin 30}$ , $\phi = 47.73°$

- When the ray travels from oil to water :

$\frac{n_{water}}{n_{oil}} = \frac{\sin 30}{\sin \theta}$ , $\frac{1.33}{1.48} = \frac{\sin 30}{\sin \theta}$ , $\theta = 33.81°$

41 ⓓ 25.9°

42 (i) ⓒ 41.68°

$n_{water} = \frac{\sin \phi}{\sin \theta}$ , $1.33 = \frac{\sin \phi}{\sin 30}$ , $\phi = 41.68°$

(ii) ⓑ 41.68°

The light ray falls normally on the plane of the mirror, so it gets reflected on itself and falls on the separating surface with an angle that equals 30°.

$n_{water} \sin \phi = n_{air} \sin \theta$ , $1.33 \sin 30 = \sin \theta$

, $\theta = 41.68°$

43 ⓒ 50°, 30°

• In a cuboid, the angle of incidence of a light ray in air always equal to its angle of emergence to air from the face that is parallel to the face of incidence.

$\therefore$ The angle of incidence in air = 50°

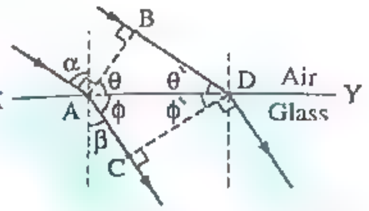
$n = \frac{\sin \phi}{\sin \theta}$ , $1.53 = \frac{\sin 50}{\sin \theta}$ , $\theta = 30°$

**44** (d)

**45** (d)

**46** (a) 0°

**47** (c) $\frac{\sin \theta}{\sin \phi}$




From the geometry of the figure :

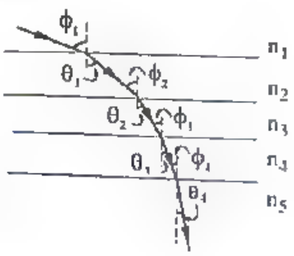
$\alpha = \theta$ , $\beta = \phi$ , $n = \frac{\sin \alpha}{\sin \beta} = \frac{\sin \theta}{\sin \phi}$

**48** (c) $n_1 < n_2, v_1 > v_2$

**49** (c)

**50** (c) 23.1°

**51** (i) (a) $n_1, n_5$ only




$\frac{\sin \phi_1}{\sin \theta_1} = \frac{n_2}{n_1}$

$\therefore \sin \theta_1 = \frac{n_1}{n_2} \sin \phi_1$

$\because \theta_1 = \phi_2$ (alternate angles)

$\therefore \frac{\sin \theta_1}{\sin \theta_2} = \frac{n_3}{n_2}$

$\therefore \sin \theta_2 = \frac{n_2}{n_3} \sin \theta_1$

$= \frac{n_2}{n_3} \times \frac{n_1}{n_2} \sin \phi_1 = \frac{n_1}{n_3} \sin \phi_1$

, and when the ray travels to $n_4$ and $n_5$ :

$\therefore \sin \theta_4 = \frac{n_1}{n_5} \sin \phi_1$

$\therefore \frac{\sin \phi_1}{\sin \theta_4} = \frac{n_5}{n_1}$

$\therefore \frac{\sin \phi_1}{\sin \theta_4}$ depends only on $n_1$ and $n_5$

(ii) (a) I

$\because \frac{\sin \phi_1}{\sin \theta_1} = \frac{v_1}{v_2}$ , $\phi_1 > \theta_1$

$\therefore \sin \phi_1 > \sin \theta_1$ $\therefore v_1 > v_2$

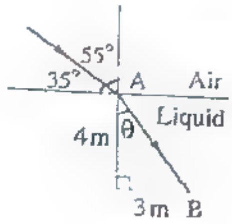
$\because \phi_2 > \theta_2$ $\therefore v_2 > v_3$

$\because \phi_3 > \theta_3$ $\therefore v_3 > v_4$

$\because \phi_4 > \theta_4$ $\therefore v_4 > v_5$

∴ The speed of light will be larger in medium 1 than the other media.

**52** (i) (d) 1.37




$\tan \theta = \frac{3}{4}$

$\theta = 36.87°$

$n = \frac{\sin \phi}{\sin \theta}$

$= \frac{\sin 55}{\sin 36.87}$

$= 1.37$

(ii) (c) $2.28 \times 10^{-8}$ s

$n = \frac{c}{v}$ , $1.37 = \frac{3 \times 10^8}{v}$

$v = 2.19 \times 10^8$ m/s

$\sin 36.87 = \frac{3}{AB}$ , $AB = 5$ m

$t = \frac{x}{v} = \frac{AB}{v} = \frac{5}{2.19 \times 10^8} = 2.28 \times 10^{-8}$ s

**53** (a) $n_1 > n_2 > n_3$

- At the boundary surface between the two media (1) and (2) :

  ∵ The light ray gets refracted away from the normal.

  $\therefore n_1 > n_2$

- At the boundary surface between the two media (2) and (3) :

  ∵ The light ray gets refracted away from the normal.

  $\therefore n_2 > n_3$ , $\therefore n_1 > n_2 > n_3$

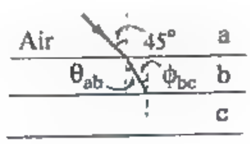
**54** (c)

**55** (i) (c) $n_2 > n_1 > n_3$

(ii) (b) $v_2 < v_1 < v_3$

**56** (a) 30.34°

When the light ray passes from medium (a) to medium (b) :




$\frac{v_a}{v_b} = \frac{\sin \phi_{ab}}{\sin \theta_{ab}}$

$\frac{1.4\, v_b}{v_b} = \frac{\sin 45}{\sin \theta_{ab}}$

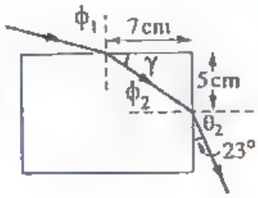
$\therefore \theta_{ab} = 30.34°$

$\because \theta_{ab} = \phi_{bc}$ (alternate angles)

$\therefore \phi_{bc} = 30.34°$

57 ⓓ 1.58

$\tan \gamma = \frac{5}{7}$




$\gamma = 35.54°$

$\because \gamma = \phi_2$ (alternate angles)

$\therefore \phi_2 = 35.54°$

$\theta_2 = 90 - 23 = 67°$

$n_{glass} \sin \phi_2 = n_{air} \sin \theta_2$

$n_{glass} = \frac{\sin \theta_2}{\sin \phi_2}$

$= \frac{\sin 67}{\sin 35.54} = 1.58$

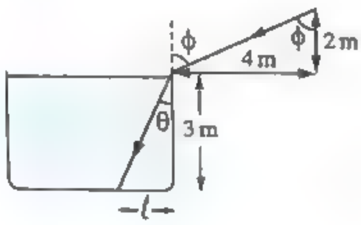
58 ⓐ $\frac{nd}{c}$

59 ⓐ $8.87 \times 10^{-8}$ s

60 ⓓ won't change

61 ⓒ 2.71 m

$\tan \phi = \frac{4}{2}$




$\phi = 63.43°$

$n = \frac{\sin \phi}{\sin \theta}$

$\frac{4}{3} = \frac{\sin 63.43}{\sin \theta}$

$\theta = 42.13°$

$\tan \theta = \frac{l}{3}$ , $\tan 42.13 = \frac{l}{3}$

$l = 2.71$ m

The length of the dark part at the bottom of the swimming pool = 2.71 m

62 ⓑ 22.08°

- When the swimmer is in air :

$n_{cornea} = \frac{\sin \phi}{\sin \theta}$ , $1.4 = \frac{\sin 30}{\sin \theta}$

$\therefore \theta = 20.92°$

- When the swimmer is in water :

$\frac{n_{cornea}}{n_{water}} = \frac{\sin \phi}{\sin \theta}$

$\frac{1.4}{1.33} = \frac{\sin \phi}{\sin 20.92}$ , $\therefore \phi = 22.08°$

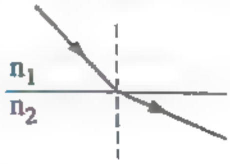
63 ⓑ descending gradually

## Second Essay questions

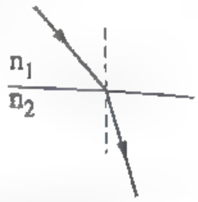
1 Yes, when the angle of incidence increases, the ray deflects toward the direction of (2) to increase the angle of reflection because; The angle of incidence = The angle of reflection

2 The angle of refraction = zero, because the ray is falling perpendicularly on the boundary surface, so it will not suffer any refraction.

3 (a)




(b)




4 (1) Because when the outside is dark, the amount of light passing from outside to inside is very small, so the person can see his image as a result of the reflection of the small amount of light reflected by the glass of the room's window and when there is light outside, the amount of light passing from outside to inside is larger than the amount of the reflected light, so it is difficult for the person to see his image by reflection.

(2) Because the absolute refractive index is the ratio between the speed of light in space and the speed of light in the medium ($n = \frac{c}{v}$), where the speed of light in space (c) is always greater than its speed in any other medium, so the ratio is always greater than 1, on the other hand the relative refractive index is given by (${}_1n_2 = \frac{v_1}{v_2}$) and if the speed of light in the first medium ($v_1$) is less than in the second medium ($v_2$), the ratio between them will be less than one and if ($v_1 > v_2$) the ratio will be greater than one.

5 When a wave moves between two media, its frequency remains constant.

$\because \frac{n_2}{n_1} = \frac{v_1}{v_2}$ $\therefore \frac{v_1}{v_2} > 1$ $\therefore v_1 > v_2$

$\therefore$ Its speed decreases.

$\because v = \lambda \nu$ $\therefore v \propto \lambda$

$\therefore$ Its wavelength decreases.

6 $\because$ Angle of incidence = Angle of reflection

$\therefore$ When increasing the angle of incidence, the angle of reflection (a) increases.

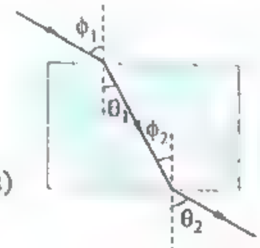
$\because {}_1n_2 = \frac{\sin a}{\sin b}$

$\because$ The relative refractive index between two media is a constant value.

$\therefore$ When increasing the angle of incidence, the angle of refraction (b) increases.

7 Yes, because the refractive index of glass changes by changing of the wavelength of the falling ray and hence the angle of refraction of blue light will be different than that of red light.

8 $\because n = \dfrac{\sin \phi_1}{\sin \theta_1}$

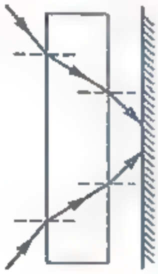



$n = \dfrac{\sin \theta_2}{\sin \phi_2}$

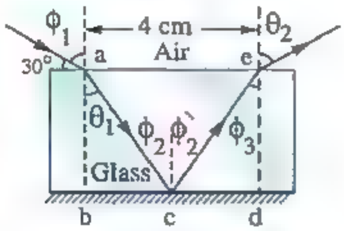
$\because \theta_1 = \phi_2$ (alternate angles)

$\therefore \phi_1 = \theta_2$

9 No, the glass plate changes the paths of the two rays and displaces their points of incidence away from each other as shown in the opposite figure.



10




$\phi_1 = 90° - 30° = 60°$

$n = \dfrac{\sin \phi_1}{\sin \theta_1}$

$\sqrt{3} = \dfrac{\sin 60}{\sin \theta_1}$

$\theta_1 = 30°$

$\because \theta_1 = \phi_2 = 30°$ (alternate angles)

$\therefore \phi_2 = \phi_2^{`} = 30°$

$\because \phi_3 = \phi_2^{`} = 30°$ (alternate angles)

$\therefore n = \dfrac{\sin \theta_2}{\sin \phi_3}$

$\sqrt{3} = \dfrac{\sin \theta_2}{\sin 30}$

$\theta_2 = 60°$

$\because \ell_{bc} = \ell_{cd} = \dfrac{\ell_{ae}}{2} = 2 \text{ cm}$

$\tan \phi_3 = \dfrac{\ell_{cd}}{\ell_{ed}}$

$\ell_{ed} = \dfrac{\ell_{cd}}{\tan \phi_3} = \dfrac{2}{\tan 30} = 3.46 \text{ cm}$

$\therefore$ The thickness of the cuboid = 3.46 cm

11 (a) ① (b) ③ (c) ②

12 In the empty cup, you won't be able to see the bottom of the cup, so you will not see the coin (Figure 2), but in the case of the cup containing water, when a light ray moves from the water (the optically denser medium) to the air (the optically rarer medium), the ray gets refracted away from the normal so that the image of the coin seems at the extension of the light ray that reaches the observer (Figure 1).

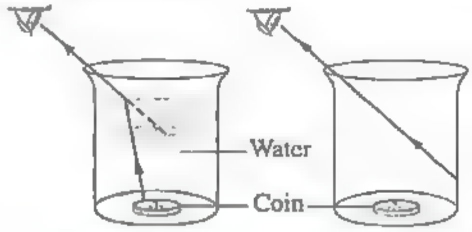



Figure (1) Figure (2)

## Answers of New Types of questions

### First Choose two correct answers

1 ⓐ be reflected from mirror Ⓐ with an angle of reflection 30°

ⓔ not be incident on mirror Ⓑ

2 ⓐ its speed becomes $\dfrac{n_1}{n_2} v_1$

ⓒ its wavelength becomes $\dfrac{n_1}{n_2} \lambda_1$

### Second Put in front of each of the following sentences the suitable number of the phenomenon that represents it

| | | |
|---|---|---|
| (1) ② | (2) ① | (3) ① |
| (4) ② | (5) ② | (6) ① |

## Chapter 2 Lesson Two

### First Multiple choice questions

1 ⓒ the superposition of waves

2 ⓐ phase

3 ⓓ the distance between the double-slit barrier and the light source

4 ⓑ the distance between the double-slit and the observation screen increases

5 ⓐ

6 ⓑ

7 ⓓ doesn't change

8 ⓐ 5000 Å

9 ⓑ $10^{-4}$ m

$$\text{Slope} = \frac{\Delta(\Delta y)}{\Delta\lambda} = \frac{(7-0)\times 10^{-3}}{(700-0)\times 10^{-9}} = 10^4$$

$$\because \Delta y = \frac{\lambda R}{d}$$

$$\therefore d = \frac{\lambda R}{\Delta y} = \frac{R}{\text{Slope}} = \frac{1}{10^4} = 10^{-4}\ \text{m}$$

10 ⓑ $5.63 \times 10^{14}$ Hz

$$\Delta y = \frac{x}{N} = \frac{0.6}{3} = 0.2\ \text{mm}$$

$$\lambda = \frac{d\Delta y}{R} = \frac{1.6\times 10^{-3}\times 0.2\times 10^{-3}}{60\times 10^{-2}} = 5.33\times 10^{-7}\ \text{m}$$

$$\upsilon = \frac{c}{\lambda} = \frac{3\times 10^8}{5.33\times 10^{-7}} = 5.63\times 10^{14}\ \text{Hz}$$

11 ⓑ $\Delta y = 10^4\,\lambda$    12 ⓒ

13 ⓓ $5\times 10^{-7}$ m

$$\text{Slope} = \frac{\Delta y}{\Delta\left(\frac{1}{d}\right)} = \frac{(10-4)\times 10^{-4}}{1000-400} = 10^{-6}\ \text{m}^2$$

$$\lambda = \frac{d\Delta y}{R} = \frac{\text{Slope}}{R} = \frac{10^{-6}}{2} = 5\times 10^{-7}\ \text{m}$$

14 ⓑ 0.8 m

$$\Delta y = \frac{x}{N} = \frac{0.6}{3} = 0.2\ \text{mm}$$

$$R = \frac{d\Delta y}{\lambda} = \frac{2\times 10^{-3}\times 0.2\times 10^{-3}}{500\times 10^{-9}} = 0.8\ \text{m}$$

15 ⓐ greater than one

16 ⓓ 0.2 mm

$$\frac{\lambda_g}{\lambda_v} = \frac{(\Delta y)_g}{(\Delta y)_v}$$

$$\frac{550}{400} = \frac{0.275}{(\Delta y)_v}$$

$$(\Delta y)_v = \frac{400\times 0.275}{550} = 0.2\ \text{mm}$$

17 ⓓ 0.08 mm

$$\because \Delta y = \frac{R\lambda}{d}$$

$$\therefore \frac{(\Delta y)_1}{(\Delta y)_2} = \frac{\lambda_1}{\lambda_2}$$

$$\frac{\frac{\Delta y}{2}}{\frac{\Delta y}{2} + 0.01} = \frac{400}{600}$$

$$\frac{\Delta y}{\Delta y + 0.02} = \frac{2}{3}$$

$\therefore \Delta y = 0.04$ mm

$\therefore$ The distance between the central fringe and the second maxima in the first case :

$x = \Delta y N = 0.04 \times 2 = 0.08$ mm

18 ⓐ $\frac{3}{10}\,x$

To find the distance between two successive fringes of the same type :

$$\Delta y = \frac{x\ (\text{Total distance})}{N\ (\text{Number of fringes})} = \frac{x}{5}$$

To find the distance between the second minima and the central maxima $(x_1)$ :

$$\Delta y = \frac{x_1}{N}$$

$$\frac{x}{5} = \frac{x_1}{1.5} \qquad \therefore x_1 = \frac{3}{10}\,x$$

19 ⓑ less than one

$$\because \Delta y = \frac{x}{N}$$

$$\therefore (\Delta y)_r = \frac{x}{5} \quad , \quad (\Delta y)_b = \frac{x}{3}$$

$$\because R = \frac{d\Delta y}{\lambda}$$

$$\therefore \frac{R_r}{R_b} = \frac{(\Delta y)_r\,\lambda_b}{(\Delta y)_b\,\lambda_r} = \frac{\left(\frac{x}{5}\right)\lambda_b}{\left(\frac{x}{3}\right)\lambda_r} = \frac{3\,\lambda_b}{5\,\lambda_r}$$

$$\because \lambda_r > \lambda_b \qquad \therefore \frac{R_r}{R_b} < 1$$

20 ⓒ 3

$$\Delta y = \frac{\lambda R}{d}$$

$$\therefore \frac{(\Delta y)_r}{(\Delta y)_v} = \frac{\lambda_r}{\lambda_v} = \frac{6000}{4000} = \frac{3}{2}$$

$$\therefore (\Delta y)_r = \frac{3}{2}\,(\Delta y)_v$$

$$2\,(\Delta y)_r = 3\,(\Delta y)_v$$

$\therefore$ The third maxima ($m = 3$) for the violet light has the same position of the second maxima ($m = 2$) of the red light.

21 ⓐ 0

22 ⓓ $4\,\lambda$

23 ⓒ the second dark fringe

24 ⓑ red light    25 ⓑ B    26 ⓓ D

27 ⓒ become thinner

$$\because \Delta y = \frac{\lambda R}{d} \qquad \therefore \Delta y \propto \lambda \quad , \quad \because n_{water} > n_{air}$$

$\therefore$ The wavelength of the used light decreases inside water than in air.

$\therefore (\Delta y)_{water} < (\Delta y)_{air}$

$\therefore$ In the same range on the screen a greater number of fringes get formed with lesser widths than what are formed in the case of air.

$\therefore$ The correct choice is ⓒ.

28 ⓒ $\frac{\Delta y}{n}$

29 ⓓ the direction of propagation

30 ⓓ $10^{-5}$ m

31 ⓑ Microwaves

32 ⓐ diffraction

33 ⓒ the short wavelengths of visible light

34 ⓐ

35 ⓐ Decreasing, Increasing

36 ⓓ the frequency

37 ⓑ Interference, Diffraction

## Second Essay questions

1 The interference pattern will be more noticeable when the distance between the interference fringes increases as ($\Delta y = \frac{\lambda R}{d}$) and there are three ways to increase the resolution of the interference pattern :

① Increasing the wavelength of the used monochromatic light where ($\Delta y \propto \lambda$).

② By increasing the distance between the double-slit and the observation screen where ($\Delta y \propto R$), so as R increases $\Delta y$ increases and the fringes appear more obviously.

③ Decreasing the distance between the two slits where ($\Delta y \propto \frac{1}{d}$), so as d decreases $\Delta y$ increases.

2 A : Constructive interference.
B : Destructive interference.

3 (a) Increases.
(b) Decreases.
(c) Increases.
(d) Increases.

4 (a) Light consists of waves which suffer interference.
(b) Because it has one wavelength which make interference pattern appears.
(c) By using a double-slit barrier in the path of the monochromatic light rays.

5 (1) Because it is formed at equal distances from the two slits, where the path difference between the two waves $(m\lambda) = 0$
(2) It may be because that the aperture size is larger than the wavelength of the incident light.
(3) Because both happen due to the same phenomenon of wave superposition.

6 The phenomenon of the interference of light waves.

7

| | Direction | Frequency | Wavelength | Speed | Dark fringes | Propagation medium |
|---|---|---|---|---|---|---|
| Reflection | Changes | Constant | Constant | Constant | Isn't formed | Constant |
| Refraction | Changes | Constant | Changes | Changes | Isn't formed | Changes |
| Interference | – | Constant | Constant | Constant | Is formed | Constant |
| Diffraction | Changes | Constant | Constant | Constant | Is formed | Constant |

## Answers of New Types of questions

### First Choose two correct answers

1 ⓑ Decreasing distance R to 0.5 m.
ⓔ Increasing distance d to 2 mm.

2 ⓐ a light of frequency less than $\upsilon$
ⓓ an aperture of size less than d

### Second Put in front of each of the following sentences the suitable number of the region that represents it

(1) ①　(2) ②　(3) ③
(4) ③　(5) ①　(6) ②

## Chapter 2 Lesson Three

### First Multiple choice questions

1 ⓑ greater than the critical angle

2 ⓒ Ray (3)　3 ⓓ material z to material y

4 ⓒ　5 ⓓ　6 ⓒ 90°

7 ⓒ the absolute refractive indices of the two media

8 ⓒ

9 ⓓ 48.5°

$$n = \frac{\sin\phi}{\sin\theta} = \frac{\sin 30^\circ}{\sin 22^\circ} = 1.335$$

$$\sin\phi_c = \frac{1}{n} \quad , \quad \sin\phi_c = \frac{1}{1.335}$$

$$\phi_c = 48.5^\circ$$

10 ⓓ 1.49　11 ⓑ 45°

12 ⓑ 1.07

13 ⓒ 53.13° inside the glass

14 ⓓ $(\phi_c)_x < (\phi_c)_y < (\phi_c)_z$

Total internal reflection could happen when the light ray is incident from an optically denser medium on its boundary with an optically rarer medium.

$\therefore n_x > n_y \quad , \quad n_y > n_z$

$\therefore n_x > n_y > n_z \qquad \because \sin\phi_c = \frac{1}{n}$

$\therefore (\phi_c)_x < (\phi_c)_y < (\phi_c)_z$

**15** ⓑ

**16** ⓐ 26.32°

$\sin\phi_c = \frac{1}{n} = \frac{v}{c} = \frac{1.33 \times 10^8}{3 \times 10^8}$

$\phi_c = 26.32°$

**17** ⓓ $\frac{v}{\sin\phi_c}$

**18** (i) ⓑ 0.9

$$_g n_w = \frac{n_w}{n_g} = \frac{\frac{1}{\sin(\phi_c)_w}}{\frac{1}{\sin(\phi_c)_g}} = \frac{\sin(\phi_c)_g}{\sin(\phi_c)_w}$$

$$= \frac{\sin 42°}{\sin 48°} = 0.9$$

(ii) ⓒ 64.16°

$\sin\phi_c = \frac{n_w}{n_g} = {}_g n_w = 0.9$

The critical angle from glass to water :

$\therefore \phi_c = 64.16°$

**19** ⓒ 46.66°

$\sin\phi_c = \frac{n_x}{n_y} = \frac{v_y}{v_x} = \frac{\lambda_y}{\lambda_x} = \frac{4000}{5500} \quad , \quad \phi_c = 46.66°$

**20** ⓓ 46.4°

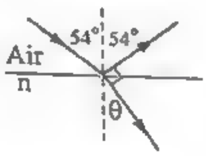
From the figure :

$\theta = 180 - (90 + 54) = 36°$

$n = \frac{\sin\phi}{\sin\theta} = \frac{\sin 54}{\sin 36} = 1.38$

$\sin\phi_c = \frac{1}{n} = \frac{1}{1.38}$

$\therefore \phi_c = 46.4°$




**21** ⓐ is greater than one

**22** ⓒ total internal reflection of light

**23** ⓑ

**24** ⓑ

**25** ⓐ $n_3 < n_2 < n_1$

**26** ⓑ $n_z < n_y < n_x$

$\because$ At the interface between the two media x and y, the ray is refracted away from the normal.

$\therefore n_x > n_y$

$\because$ At the interface between the two media y and z, the ray suffers a total internal reflection.

$\therefore n_y > n_z \quad , \quad \therefore n_z < n_y < n_x$

**27** ⓐ is higher in medium x

**28** ⓑ $n_y < n_x < n_z$

$\because$ Ray (1) suffers a total internal reflection in medium z.

$\therefore n_z > n_y$

$\because$ Ray (2) is refracted tangent to the boundary surface between the two media x and z.

$\therefore n_z > n_x$

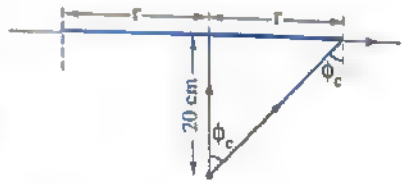
$\because$ The two rays (1) and (2) are incident with the same angle of incidence.

$\therefore (\phi_c)_{zy} < (\phi_c)_{zx}$

$\because \sin\phi_c = {}_{denser}n_{rarer} = \frac{n_{rarer}}{n_{denser}} \qquad \therefore \frac{n_y}{n_z} < \frac{n_x}{n_z}$

$\therefore n_y > n_x \quad , \quad n_y < n_x < n_z$

**29** (i) ⓒ 20 cm




$\sin\phi_c = \frac{1}{n}$

$= \frac{1}{\sqrt{2}}$

$\phi_c = 45°$

$\tan\phi_c = \frac{r}{20}$

$r = 20 \tan\phi_c$

$= 20 \tan 45 = 20$ cm

(ii) ⓐ increase

If the depth of the lamp is increased, the radius of the disk that is needed to block its light has to be increased.

**30** ⓑ greater than 1

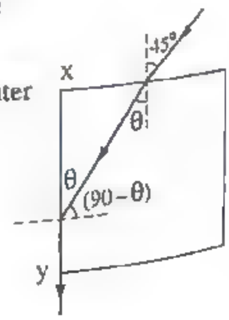
$\because {}_{glass}(\sin\phi_c)_{gasoline} = \sin(\phi_c)_1 = \frac{n_{gasoline}}{n_{glass}}$

$\because {}_{glass}(\sin\phi_c)_{water} = \sin(\phi_c)_2 = \frac{n_{water}}{n_{glass}}$

$\therefore \frac{\sin(\phi_c)_1}{\sin(\phi_c)_2} = \frac{n_{gasoline}}{n_{water}}$

$\because n_{gasoline} > n_{water} \qquad \therefore \frac{(\phi_c)_1}{(\phi_c)_2} > 1$

**31** ⓒ 1.225




- When the ray falls on the outer surface of the glass slab :

$n = \frac{\sin\phi}{\sin\theta} = \frac{\sin 45}{\sin\theta} \qquad ①$

- When the ray falls on the inner surface of the glass slab :

$n = \frac{\sin 90}{\sin(90-\theta)} = \frac{1}{\cos\theta}$ (2)

From equations (1) and (2):

$\frac{\sin 45}{\sin\theta} = \frac{1}{\cos\theta}$

$\sin 45 = \frac{\sin\theta}{\cos\theta} = \tan\theta$

$\theta = 35.26°$

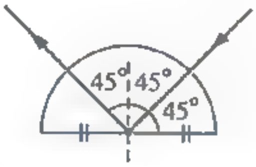
$n = \frac{\sin 45}{\sin 35.26} = 1.225$

32 ⓒ

$\sin\phi_c = \frac{1}{n} = \frac{1}{1.5}$ ,

$\phi_c = 41.81°$ ,

$\because \phi > \phi_c$




∴ The ray undergoes total internal reflection and it emerges as in the opposite figure :

∴ The correct path of the ray is ⓒ.

33 (i) ⓓ undergoes total internal reflection
(ii) ⓓ emerges tangent to that face

34 ⓒ The intensity of ray bz increases.

35 ⓓ Violet

36 ⓐ yellow, orange and red

37 ⓐ It undergoes a total internal reflection by an angle of 58.97°

38 ⓒ 2.19

39 ⓑ be refracted away from the normal

40 ⓓ k

41 ⓐ x

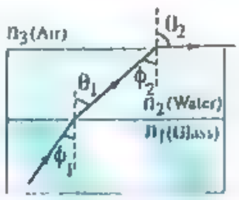
42 ⓓ 90°

- Before putting the water layer :

$\sin\phi_c = \frac{1}{n}$

$\therefore n_1 \sin\phi_c = 1$ (1)

- After putting the water layer :




$\because \phi_1 = \phi_c$

$\therefore n_1 \sin\phi_c = n_2 \sin\theta_1$

Substituting from equation (1):

$\therefore n_2 \sin\theta_1 = 1$

$\because \theta_1 = \phi_2$ (alternate angles)

$\therefore n_2 \sin\phi_2 = 1$

$\because n_2 \sin\phi_2 = n_3 \sin\theta_2$

$\because n_3 = 1$

$\therefore \sin\theta_2 = 1$

$\therefore \theta_2 = 90°$

## Second Essay questions

1 (1) Because the light ray may fall with an angle less than the critical angle.

(2) Because the light ray may fall from water (optically denser medium) to air (optically rarer medium) with an angle greater than the critical angle, so it undergoes total internal reflection

(3) Because they reflect light multiple times inside them until it emerges from the other end due to the phenomenon of total internal reflection without a loss in the light energy so that they can be used to direct light into places that are hard to reach.

(4) Because prisms reflect light totally with minimal loss and also mirror loses its efficiency with time.

(5) Because light rays refract several times when they travel from cold air (in the upper layers) to hot air (in the lower layers) until a total internal reflection happens to the light and appears as if it is coming from a reflecting surface.

2 - **The first ray :** Travel without any deviation at an angle of refraction = 0°

- **The second ray :**

$\sin\phi_c = \frac{1}{n} = \frac{1}{\sqrt{2}}$

$\therefore \phi_c = 45°$

∵ The ray falls at an angle of 30° which is less than $\phi_c$

∴ The ray refracts with an angle of refraction that can be found from the relation :

$\frac{n_{air}}{n_{water}} = \frac{\sin\phi}{\sin\theta}$

$\sin\theta = \sqrt{2}\sin 30$

$\theta = 45°$

- **The third ray :** Refracts tangentially to the boundary surface because its angle of incidence equals the critical angle between the two media $\phi_c$.

- **The fourth ray :** Suffers total internal reflection with angle of reflection = 60° because its angle of incidence > $\phi_c$

3 (a) Because light falls on the surfaces at these two regions by an angle greater than the critical angle between the two media.

(b) $\sin \phi_c = \frac{1}{n} = \frac{1}{1.33}$

$\phi_c = 48.75°$

$\because \theta = \phi_c$ (alternate angles)

$\therefore \theta = 48.75°$

4 (a) Because the light ray falls normally on the boundary surface.

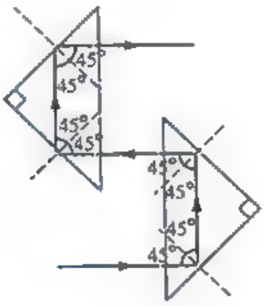
(b) Because the light ray falls at angle greater than the critical angle as the refractive index of the outer layer is less than that of the inner layer.

(c) Because the outer layer reflects the light that may escape from the inner layer, so the double layer fiber decreases the loss of light rays.

5 (a) Aluminum fluoride and magnesium fluoride.

(b) The second prism because the used thin film decreases the loss during the entrance and emergence of light rays, so the efficiency of the prism increases.

6

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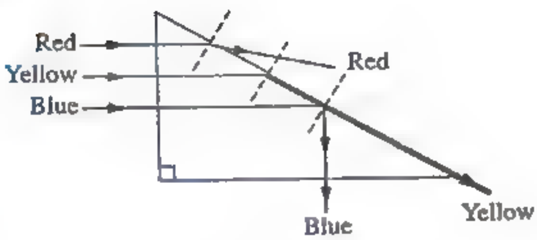
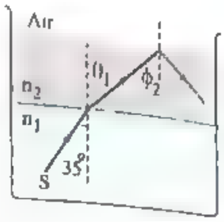



As $n \propto \frac{1}{\lambda}$ and $\sin \phi_c = \frac{1}{n}$, so $\sin \phi_c \propto \lambda$, hence the critical angle of red light is larger than that of yellow, so it refracts and emerges from the surface of the prism which is opposite to the right angle away from the normal, while the critical angle of blue light is less than that of yellow, so it suffers total internal reflection inside the prism and falls perpendicular on the other side of the right angle.

8 $\sin (\phi_c)_{12} = \frac{n_2}{n_1} = \frac{1.5}{2}$




$\therefore (\phi_c)_{12} = 48.59°$

$\therefore$ The ray falls on the interface between the two layers with an angle less than $\phi_c$, so it refracts into the upper layer.

$\frac{n_2}{n_1} = \frac{\sin \phi_1}{\sin \theta_1}$

$\frac{1.5}{2} = \frac{\sin 35}{\sin \theta_1}$

$\therefore \theta_1 = 49.89°$

$\because \theta_1 = \phi_2$ (alternate angles)

$\therefore \phi_2 = 49.89°$

$\sin (\phi_c)_2 = \frac{1}{n_2} = \frac{1}{1.5}$

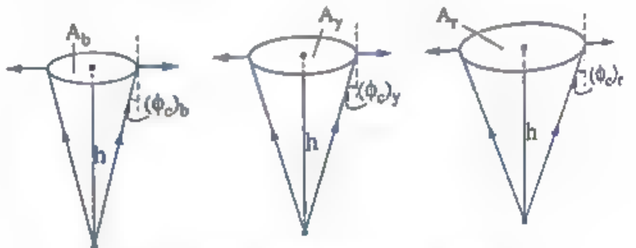
$(\phi_c)_2 = 41.81°$

$\therefore$ The ray falls at an angle larger than the critical angle, so it reflects totally in the upper medium and doesn't emerge to air.

9 $\because \sin \phi_c \propto \frac{1}{n}$

$\because n \propto \frac{1}{\lambda}$ $\qquad \therefore \sin \phi_c \propto \lambda$

$\because \lambda_r > \lambda_y > \lambda_b$ $\qquad \therefore (\phi_c)_r > (\phi_c)_y > (\phi_c)_b$




So, as the critical angle increases the range of angles of incidence increases and the light rays become able to refract at large distances from the light source and the radius of the light spot increases, so the area of red light > The area of yellow light > The area of blue light

10 (a) At the interface between (2) and (3) :

$n_2 \sin (\phi_c)_{23} = n_3 \sin 90$

$n_2 \sin (90 - \theta) = n_3 \sin 90$

$1.4 \cos \theta = 1.2$

$\therefore \theta = 31°$

At the interface between (1) and (2) :

$\frac{n_2}{n_1} = \frac{\sin\phi}{\sin\theta}$

$\frac{1.4}{1.6} = \frac{\sin\phi}{\sin 31}$

$\therefore \phi = 26.79°$

(b) At increasing the angle $\phi$, the angle of refraction $\theta$ increases and as ($\phi_2 = 90 - \theta$), so when $\theta$ increases $\phi_2$ decreases until it gets less than the critical angle and the ray passes to medium 3 (where : $\phi_2$ is the angle of incidence on the interface between the two media 2 and 3).

## Answers of New Types of questions

### First Choose two correct answers

1. ⓑ the absolute refractive index of the material of prism ① = 2.1

   ⓒ the relative refractive index from material of prism ① to that of prism ② = 0.64

2. ⓑ , ⓒ

### Second Put in front of each of the following sentences the suitable number of the figure that represents it

| | | |
|---|---|---|
| (1) ① | (2) ① | (3) ② |
| (4) ② | (5) ① | |

## Chapter 2 Lesson Four

### First Multiple choice questions

1. ⓓ x = b + c
2. ⓑ Angle y
3. ⓐ
4. ⓐ (I) , (II)
5. ⓓ 59.82°

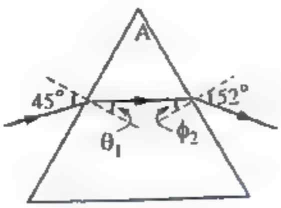
- Applying Snell's law at the first refraction :

$\sin\phi_1 = n \sin\theta_1$

$\sin\theta_1 = \frac{\sin 45}{1.5}$

$\theta_1 = 28.13°$

- Applying Snell's law at the second refraction :




$n \sin\phi_2 = \sin\theta_2$

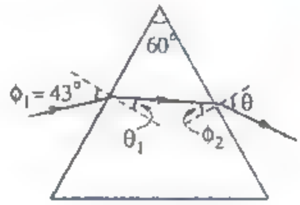
$\sin\phi_2 = \frac{\sin 52}{1.5}$

$\phi_2 = 31.69°$

$A = \theta_1 + \phi_2 = 28.13 + 31.69 = 59.82°$

6. ⓒ 54.8°

- Applying Snell's law at the first refraction :




$\sin\phi_1 = n \sin\theta_1$

$\sin\theta_1 = \frac{\sin 43}{1.5}$

$\theta_1 = 27°$

$A = \theta_1 + \phi_2$

$\phi_2 = 60 - 27 = 33°$

- Applying Snell's law at the second refraction :

$\sin\theta = n \sin\phi_2 = 1.5 \times \sin 33$

$\theta = 54.8°$

7. ⓑ 28.38°

$A = 180 - (50 + 68) = 62°$

$\phi_1 = 90 - 30 = 60°$ , $\theta_1 = 90 - 50 = 40°$

$n = \frac{\sin\phi_1}{\sin\theta_1} = \frac{\sin 60}{\sin 40} = 1.35$ , $\phi_2 = 90 - 68 = 22°$

$n = \frac{\sin\theta_2}{\sin\phi_2}$ , $\sin\theta_2 = n \sin\phi_2 = 1.35 \sin 22$

$\therefore \theta_2 = 30.38°$

$\alpha = \phi_1 + \theta_2 - A$

$= 60 + 30.38 - 62 = 28.38°$

8. ⓒ $\theta_1$ increases and $\phi_2$ decreases.

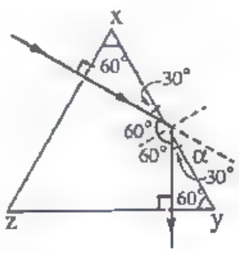
9. ⓒ $\frac{4}{3}$ A

$\because \alpha = \phi_1 + \theta_2 - A$  $\therefore \phi_1 + \theta_2 = 2A$

$\because \phi_1 > \theta_2$  $\therefore 2A > \phi_1 > A$

$\therefore$ The correct choice is ⓒ.

10. ⓒ 15°
11. ⓑ 53.9°
12. ⓓ All the previous.
13. ⓓ deviates from its path by an angle of 60°




$\phi_1 = \theta_1 = 0°$

$\because A = \theta_1 + \phi_2$

$\phi_2 = A = 60°$

$\because \sin\phi_c = \frac{1}{n} = \frac{1}{\sqrt{2}}$

$\phi_c = 45°$

$\therefore \phi_2 > \phi_c$

$\therefore$ The ray undergoes a total internal reflection and deviates from its path by an angle of 60°

**14** ⓑ less than 45°

**15** ⓑ less than angle θ

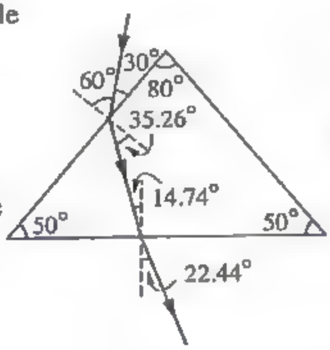
**16** ⓒ 32.44°

- Applying Snell's law at the first refraction :

$\sin\phi_1 = n\sin\theta_1$ , $\sin\theta_1 = \frac{\sin 60}{1.5}$ ,

$\therefore \theta_1 = 35.26°$

$\because$ The apex angle of the prism is the angle between the two faces of the prism that refract light at its entrance and emergence from the prism.




$\therefore A = 50°$

$A = \theta_1 + \phi_2$

$50 = 35.26 + \phi_2$

$\therefore \phi_2 = 14.74°$

• Comparing the second angle of incidence ($\phi_2$) with the critical angle of the prism material ($\phi_c = 41.8°$), we find that $\phi_2 < \phi_c$

- Snell's law is applied at the second refraction :

$\sin\theta_2 = n\sin\phi_2 = 1.5\sin 14.74$

$\therefore \theta_2 = 22.44°$

$\alpha = \phi_1 + \theta_2 - A$

$= 60 + 22.44 - 50 = 32.44°$

**17** (i) ⓒ 45°

$A = \phi_2 + \theta_1$

$\phi_2 = A - \theta_1 = 30 - 0 = 30°$

• Comparing the second angle of incidence ($\phi_2$) with the critical angle of the prism material ($\phi_c = 45°$), we find that $\phi_2 < \phi_c$

$\therefore$ Snell's law is applied at the second refraction :

$\sin\theta_2 = n\sin\phi_2 = \sqrt{2}\sin 30$ , $\theta_2 = 45°$

(ii) ⓐ 15°

$\alpha = \phi_1 + \theta_2 - A = 0 + 45 - 30 = 15°$

**18** ⓒ $\sqrt{2}$

$\because$ The ray fell perpendicularly.

$\therefore \theta_1 = 0°$ , $\therefore A = \phi_2$

$\because \phi_2 = \phi_c$

$\therefore n = \frac{1}{\sin\phi_c} = \frac{1}{\sin A} = \frac{1}{\sin 45} = \sqrt{2}$

**19** ⓒ 1.53

$A = \theta_1 + \phi_2$ , $\theta_1 = 0°$

$\therefore \phi_2 = 30°$

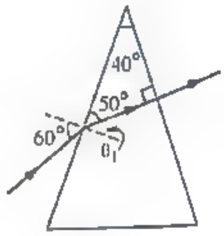
$\alpha = \phi_1 + \theta_2 - A$ , $\phi_1 = 0°$

$20 = \theta_2 - 30$

$\therefore \theta_2 = 50°$

$n = \frac{\sin\theta_2}{\sin\phi_2} = \frac{\sin 50}{\sin 30} = 1.53$

**20** ⓐ 1.35




$A = \theta_1 + \phi_2$

$\because \phi_2 = 0°$

$\therefore \theta_1 = 40°$

$\therefore n = \frac{\sin\phi_1}{\sin\theta_1}$

$= \frac{\sin 60}{\sin 40} = 1.35$

**21** ⓑ 42°

$A = \theta_1 + \phi_2$

$72 = 30 + \phi_2$ , $\phi_2 = 42°$

$\because$ The ray emerges tangent to the prism face.

$\therefore \phi_c = \phi_2 = 42°$

**22** ⓒ 48.59°

$\because \phi_1 = \theta_1 = 0°$ $\therefore \phi_2 = 60°$

$\sin\phi_c = \frac{1}{n} = \frac{1}{1.5}$ $\phi_c = 41.81°$

$\because$ Angle of incidence ($\phi_2$) inside the prism = 60°

*i.e.* it is greater than the critical angle.

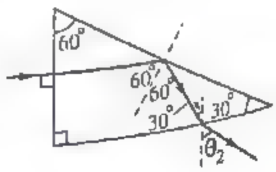
$\therefore$ The light ray reflects totally inside the prism and falls on the other face of the prism by an angle 30° which is less than the critical angle, so it emerges by an emergence angle $\theta_2$.

Applying Snell's law :

$\sin\theta_2 = n\sin\phi_3$

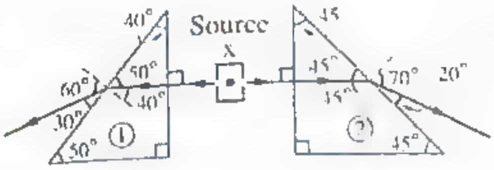
$= 1.5 \times \sin 30$

$\therefore \theta_2 = 48.59°$




**23** ⓓ 53°

24 ⓑ $n_2 < n_1$




$\because n_1 = \frac{\sin 60}{\sin 40} = 1.35$

$\because n_2 = \frac{\sin 70}{\sin 45} = 1.33$

$\therefore n_2 < n_1$

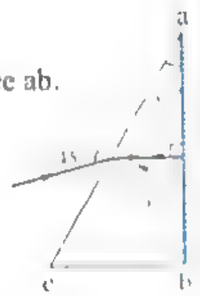
25 ⓓ The angle of emergence ($\theta_2$).

26 ⓐ Point x

27 ⓓ

28 ⓓ 4

29 ⓑ $\sqrt{2}$




$\because$ The ray retraces its path.

$\therefore$ The ray is incident normal to face ab.

$\therefore \phi_2 = 0°$

$A = \theta_1 + \phi_2$

$\therefore \theta_1 = A = 30°$

$n = \frac{\sin \phi_1}{\sin \theta_1} = \frac{\sin 45}{\sin 30} = \sqrt{2}$

30 ⓓ $\frac{3\sqrt{3}}{4}$

$A = \theta_1 + \phi_2$

$\phi_2 = A - \theta_1 = 60 - 0 = 60°$

$\because$ The ray emerges tangent to face AC.

$\therefore \phi_2 = \phi_c = 60°$ , $\sin \phi_c = \frac{n_2}{n_1}$

$\sin 60 = \frac{n}{1.5}$ , $n = 1.5 \sin 60 = \frac{3\sqrt{3}}{4}$

31 ⓒ 32.25°

$A = \theta_1 + \phi_2$

$60 = \theta + 2\theta$

$\therefore \theta = 20°$

$\because$ The ray emerges tangentially.

$\therefore \phi_2 = \phi_c = 40°$

$\therefore n = \frac{1}{\sin \phi_c} = \frac{1}{\sin 40} = 1.56$

$n = \frac{\sin \phi_1}{\sin \theta_1}$

From Snell's law at the first refraction :

$\sin \phi = n \sin \theta_1 = n \sin \theta = 1.56 \sin 20$

$\therefore \phi = 32.25°$

32 (i) ⓒ 1.49

$\tan A = \frac{\ell_{yz}}{\ell_{xy}}$

$= \frac{\ell_{yz}}{\frac{1}{2}\ell_{yz}} = 2$

$\therefore A = 63.43°$

$A = \theta_1 + \phi_2$

$63.43 = \frac{1}{2}\phi_2 + \phi_2 = \frac{3}{2}\phi_2$

$\therefore \phi_2 = 42.29°$

$\because$ The ray emerges tangentially.

$\therefore \phi_c = \phi_2 = 42.29°$

$\therefore n = \frac{1}{\sin \phi_c} = \frac{1}{\sin 42.29} = 1.49$

(ii) ⓑ 59.08°

$n = \frac{\sin \phi_1}{\sin \theta_1}$

$\sin \phi_1 = n \sin \theta_1 = 1.49 \sin \left( \frac{42.29}{2} \right)$

$\therefore \phi_1 = 32.51°$

$\alpha = \phi_1 + \theta_2 - A$

$= 32.51 + 90 - 63.43 = 59.08°$

33 ⓓ 46.46°

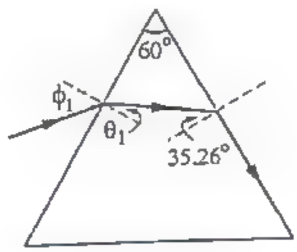
$\because n = \frac{\sin \phi_1}{\sin \theta_1}$

$\because A = \theta_1 + \phi_2$

$\therefore$ As $\phi_1$ decreases $\theta_1$ decreases and $\phi_2$ increases until $\phi_2$ equals $\phi_c$

$\sin \phi_c = \frac{1}{n} = \frac{1}{\sqrt{3}}$

$\therefore \phi_c = 35.26°$




$A = \theta_1 + \phi_2$

$60 = \theta_1 + 35.26$

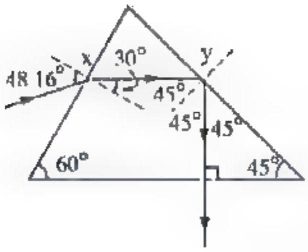
$\theta_1 = 24.74°$

$n = \frac{\sin \phi_1}{\sin \theta_1}$

$\therefore \sin \phi_1 = \sqrt{3} \sin 24.74$

$\therefore \phi_1 = 46.46°$

**34** ⓒ 48.16° , 0°




$n = \dfrac{1}{\sin \phi_c}$

$= \dfrac{1}{\sin 42} = 1.49$

$n = \dfrac{\sin \phi_1}{\sin \theta_1}$

$\sin \phi_1 = n \sin \theta_1$

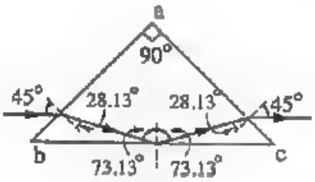
$\sin \phi_1 = 1.49 \times \sin 30$

$\phi_1 = 48.16°$

$\because \phi_2 > \phi_c$

$\therefore$ The light ray is totally reflected then it emerges perpendicularly from the prism with an angle $= 0°$

**35** ⓑ 45°




$\sin \phi_1 = n \sin \theta_1$

$\sin 45 = 1.5 \times \sin \theta_1$

$\sin \theta_1 = \dfrac{\sin 45°}{1.5}$

$\theta_1 = 28.13°$

$\sin \phi_c = \dfrac{1}{n} = \dfrac{1}{1.5}$

$\therefore \phi_c = 41.81°$

The light ray falls on face bc with angle 73.13° which is greater than the critical angle (41.81°), so it is totally reflected and falls on face ac by an angle of 28.13°.

$n \sin \phi_2 = \sin \theta_2$

$n = \dfrac{\sin \theta_2}{\sin \phi_2}$

$1.5 \sin 28.13° = \sin \theta_2$

$\theta_2 = 45°$

**36** ⓑ 10.85°

- Applying Snell's law for the light ray at the boundary surface between the two types of glass :

$n_1 \sin \phi_1 = n_2 \sin \theta_1$

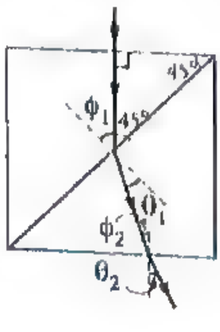
$\sin \theta_1 = \dfrac{1.3 \times \sin 45}{1.5}$

$\theta_1 = 37.79°$

$A = \theta_1 + \phi_2$

$45 = 37.79 + \phi_2$

$\phi_2 = 7.21°$




Comparing the angle of incidence ($\phi_2$) with the critical angle of glass material (2) surrounded by air ($\phi_c = 41.8°$), we find that $\phi_2 < \phi_c$

- Snell's law is applied at the second refraction :

$\sin \theta_2 = n_2 \sin \phi_2 = 1.5 \times \sin 7.21$

$\theta_2 = 10.85°$

**37** ⓐ emerges from face xy refracted away from the normal

**38** ⓐ It should be increased.

**39** ⓑ Decreasing the angle of incidence $\phi_1$

$\because n = \dfrac{\sin \phi_1}{\sin \theta_1}$

$\therefore$ When decreasing $\phi_1$, $\theta_1$ decreases as n is constant.

$\because A = \phi_2 + \theta_1$

$\therefore$ $\phi_2$ increases till it becomes greater than the critical angle between the two media, hence the light ray undergoes total internal reflection.

**40** ⓒ lies outside the prism

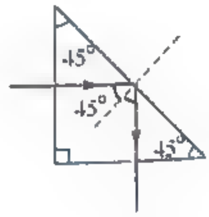
**41** ⓐ emerge with an angle smaller than 90°

## Second Essay questions

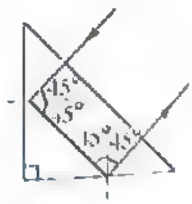
**1** $(\alpha = \phi_1 + \theta_2 - A)$

- The apex angle (A).
- The first angle of incidence ($\phi_1$).
- The refractive index of the prism (n) for the used light.

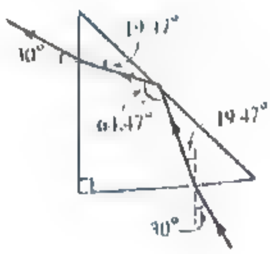
**2** (a) Figure (4).




(b , c) Figure (3).



(d) Figure (2).

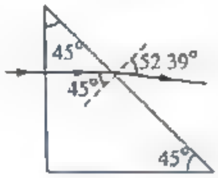


**3** The refractive index of the prism :

$n_1 = \frac{1}{\sin \phi_c} = \frac{1}{\sin 42} = 1.49$

In water : $\sin \phi_c = \frac{n_2}{n_1} = \frac{1.33}{1.49}$

$\phi_c = 63.2°$




$A = \theta_1 + \phi_2$

$45 = 0 + \phi_2$

$\phi_2 = 45°$

$\because \phi_2 < \phi_c$

$\therefore$ The ray emerges from the prism by an angle $\theta_2$ :

$n_1 \sin \phi_2 = n_2 \sin \theta_2$

$1.49 \times \sin 45 = 1.33 \times \sin \theta_2$

$\theta_2 = 52.39°$

## Answers of New Types of questions

### First Choose two correct answers

**1** ⓐ $\theta_2$ decreases
ⓓ $\theta_1$ increases

**2** ⓒ the refractive index of the liquid (n) equals $\frac{3\sqrt{3}}{4}$
ⓔ the angle of deviation of the ray equals 30°

### Second Using the figure to complete the blanks

(1) increase (2) decrease (3) decrease
(4) decrease (5) increase

## Chapter 2 Lesson Five

### First Multiple choice questions

**1** ⓒ $n = \frac{\sin \phi_1}{\sin \phi_2}$

**2** (i) ⓑ 45°

$\phi_1 = \phi_o = \frac{\alpha_o + A}{2} = \frac{30 + 60}{2} = 45°$

(ii) ⓒ 45°

$\theta_2 = \phi_1 = 45°$

**3** (i) ⓒ 60°

Position (x) represents the minimum deviation position in the prism :

$\phi_o = \frac{\alpha_o + A}{2}$ , $45 = \frac{30 + A}{2}$ , $A = 60°$

(ii) ⓑ $\sqrt{2}$

$n = \frac{\sin \phi_o}{\sin \theta_o} = \frac{\sin \phi_o}{\sin \left(\frac{A}{2}\right)} = \frac{\sin 45}{\sin \left(\frac{60}{2}\right)} = \sqrt{2}$

(iii) ⓒ 45°

At position x :

$\theta_2 = \phi_1 = \phi_o = 45°$

**4** ⓐ 30° , 45°

$n = \frac{\sin \phi_o}{\sin \theta_o} = \frac{\sin \phi_o}{\sin \left(\frac{A}{2}\right)}$ , $\sqrt{2} = \frac{\sin \phi_o}{\sin \left(\frac{60}{2}\right)}$

$\sin \phi_o = \frac{\sqrt{2}}{2}$ , $\phi_1 = \phi_o = 45°$

$\alpha_o = 2\phi_o - A = (2 \times 45) - 60 = 30°$

**5** ⓐ 30°

**6** (i) ⓐ 20°

$\because \phi_1 = \theta_2$

$\therefore$ The prism is in the minimum deviation position.

$\alpha_o = 2\phi_1 - A = (2 \times 40) - 60 = 20°$

(ii) ⓒ 1.29

$n = \frac{\sin \phi_o}{\sin \theta_o} = \frac{\sin \phi_o}{\sin \left(\frac{A}{2}\right)} = \frac{\sin 40}{\sin \left(\frac{60}{2}\right)} = 1.29$

**7** ⓒ $\sqrt{3}$

$\alpha = \phi_1 + \theta_2 - A$

$60 = 60 + \theta_2 - 60$

$\therefore \theta_2 = 60°$

$\because \phi_1 = \theta_2$

$\therefore$ The prism is at minimum deviation position.

$\therefore n = \frac{\sin \left(\frac{\alpha_o + A}{2}\right)}{\sin \left(\frac{A}{2}\right)} = \frac{\sin \left(\frac{60 + 60}{2}\right)}{\sin \left(\frac{60}{2}\right)} = \sqrt{3}$

**8** ⓑ Deviation increases, Deviation increases

**9** ⓐ greater than one.

**10** ⓑ decreases

**11** ⓓ

**12** ⓒ Red, Yellow, Blue

**13** (i) ⓐ $\sqrt{2}$

(ii) ⓒ 45°

**14** (b) b

**15** (d) 50°

**16** (b) $\frac{1}{1}$

**17** (a) increase the angle of incidence ($\phi_1$)

**18** (i) (c) 80°

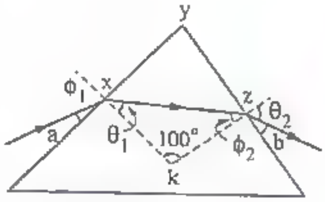
In the triangle xkz :

$\because \theta_1 + \phi_2 + 100 = 180$

$\because A = \theta_1 + \phi_2$

$\therefore A + 100 = 180$

$\therefore A = 80°$




(ii) (c) 60°

$\because \hat{a} = \hat{b}$ $\qquad \therefore \phi_1 = \theta_2$

$\therefore$ The prism is in the position of minimum deviation.

$\therefore \theta_1 = \phi_2 = \frac{A}{2} = \frac{80}{2} = 40°$

$\phi_1 = 1.5\,\phi_2 = 1.5 \times 40 = 60°$

(iii) (c) 1.35

$$n = \frac{\sin \phi_1}{\sin \theta_1} = \frac{\sin 60}{\sin 40} = 1.35$$

**19** (c) 1.53

$\phi_o = \frac{\alpha_o + A}{2}$ , $50 = \frac{\alpha_o + 1.5\,\alpha_o}{2}$ , $\alpha_o = 40°$

$A = 1.5\,\alpha_o = 1.5 \times 40 = 60°$

, $\theta_o = \frac{A}{2} = \frac{60}{2} = 30°$

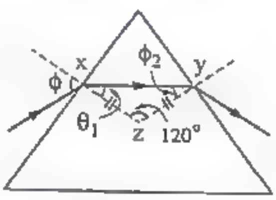
$$n = \frac{\sin \phi_o}{\sin \theta_o} = \frac{\sin 50}{\sin 30} = 1.53$$

**20** (d) 60° , 60°

$\because$ Triangle xyz is isosceles.

$\therefore \theta_1 = \phi_2 = \frac{180 - 120}{2} = 30°$

$\therefore$ The prism is in minimum deviation position.




$n = \frac{\sin \phi_1}{\sin \theta_1}$ , $\sqrt{3} = \frac{\sin \phi}{\sin 30}$ , $\phi = 60°$

$\therefore A = 2\,\theta_1 = 2 \times 30 = 60°$

$\alpha = 2\,\phi_o - A = (2 \times 60) - 60 = 60°$

**21** (i) (b) 30°

$\because$ The triangle is isosceles and the refracted ray inside the prism is parallel to the base.

$\therefore$ The prism is in minimum deviation position.

$\therefore \theta_2 = \phi_1 = 30°$

(ii) (d) 15°

$\alpha_o = 2\,\phi_1 - A = (2 \times 30) - 45 = 15°$

(iii) (c) 1.31

$$n = \frac{\sin \phi_1}{\sin \theta_1} = \frac{\sin \phi_1}{\sin\left(\frac{A}{2}\right)} = \frac{\sin 30}{\sin\left(\frac{45}{2}\right)} = 1.31$$

**22** (c)

**23** (i) (c) 10.2°

$${}_{liquid}n_{prism} = \frac{n_{prism}}{n_{liquid}} = \frac{1.5}{1.3} = 1.15$$

$${}_{liquid}n_{prism} = \frac{\sin\left(\frac{\alpha_o + A}{2}\right)}{\sin\left(\frac{A}{2}\right)}$$

$$1.15 = \frac{\sin\left(\frac{\alpha_o + 60}{2}\right)}{\sin\left(\frac{60}{2}\right)} \quad , \quad \alpha_o = 10.2°$$

(ii) (b) 35.1°

$$\phi_1 = \phi_o = \frac{\alpha_o + A}{2} = \frac{10.2 + 60}{2} = 35.1°$$

**24** (b) will decrease

**25** (b) greater, greater

**26** (c) encounters total internal reflection

**27** (a) 3°

**28** (b) 2

**29** (a) 4°

At : $n = 0$ , $\alpha_o = -A$

$\therefore -4 = -A$

$\therefore$ y-intercept represents $-A$

$\therefore A = 4°$

**30** (d) 1.5

$$\text{Slope} = \frac{\Delta \alpha_o}{\Delta A} = \frac{5 - 0}{10 - 0} = 0.5$$

$\because \alpha_o = A\,(n - 1)$

$\therefore n = \frac{\alpha_o}{A} + 1 = (\text{slope}) + 1 = 0.5 + 1 = 1.5$

**31** (c) 1.67

$\because$ The second prism cancels the deviation of the light ray caused by the first prism.

$\therefore (\alpha_o)_1 = (\alpha_o)_2$

$A_1\,(n_1 - 1) = A_2\,(n_2 - 1)$

$8\,(1.5 - 1) = 6\,(n_2 - 1)$ , $\therefore n_2 = 1.67$

**32** (b) 2.8°

$$\alpha_o = A\left(\frac{n_{prism}}{n_{liquid}} - 1\right) = 10\left(\frac{1.6}{1.25} - 1\right) = 2.8°$$

33 ⓒ less than $\alpha$

34 ⓓ 4°

$$n_y = \frac{n_b + n_r}{2} = \frac{1.6 + 1.4}{2} = 1.5$$

$$(\alpha_o)_y = A(n_y - 1) = 8(1.5 - 1) = 4°$$

35 ⓒ 0.3°

36 ⓒ $\frac{2}{11}$

37 ⓒ 0.18

38 (i) ⓒ 4° , 5.6°

$$(\alpha_o)_r = A(n_r - 1) = 8 \times (1.5 - 1) = 4°$$

$$(\alpha_o)_b = A(n_b - 1) = 8 \times (1.7 - 1) = 5.6°$$

(ii) ⓓ 1.6°

$$(\alpha_o)_b - (\alpha_o)_r = 5.6 - 4 = 1.6°$$

(iii) ⓒ 0.33

$$n_y = \frac{n_b + n_r}{2} = \frac{1.7 + 1.5}{2} = 1.6$$

$$\omega_\alpha = \frac{n_b - n_r}{n_y - 1} = \frac{1.7 + 1.5}{1.6 - 1} = 0.33$$

39 ⓒ $\frac{22}{13}$

$$\because n_y = \frac{n_b + n_r}{2} \qquad \therefore (n_y)_1 = \frac{1.56 + 1.48}{2} = 1.52$$

$$(n_y)_2 = \frac{1.69 + 1.63}{2} = 1.66$$

$$, \omega_\alpha = \frac{n_b - n_r}{n_y - 1}$$

$$\therefore \frac{(\omega_\alpha)_1}{(\omega_\alpha)_2} = \frac{(n_b)_1 - (n_r)_1}{(n_y)_1 - 1} \times \frac{(n_y)_2 - 1}{(n_b)_2 - (n_r)_2}$$

$$= \frac{(1.56 - 1.48) \times (1.66 - 1)}{(1.52 - 1) \times (1.69 - 1.63)} = \frac{22}{13}$$

40 ⓒ 1.625

$$\omega_\alpha = \frac{n_b - n_r}{n_y - 1} \quad , \quad 0.048 = \frac{(n_b)_1 - (n_r)_1}{1.5 - 1}$$

$$, (n_b)_1 - (n_r)_1 = 0.024$$

$\because$ The angular dispersions of the two prisms are equal.

$$\therefore A_1 \left((n_b)_1 - (n_r)_1\right) = A_2 \left((n_b)_2 - (n_r)_2\right)$$

$$6.25 \times 0.024 = 10 \left((n_b)_2 - (n_r)_2\right)$$

$$(n_b)_2 - (n_r)_2 = \frac{6.25 \times 0.024}{10} = 0.015$$

$$, (\omega_\alpha)_2 = \frac{(n_b)_2 - (n_r)_2}{(n_y)_2 - 1}$$

$$0.024 = \frac{0.015}{(n_y)_2 - 1} \quad , \quad (n_y)_2 = 1.625$$

## Second Essay questions

1 Light disperses into the spectrum colors.

2 (1) Because the angle of minimum deviation is defined from :

$$n = \frac{\sin\left(\frac{\alpha_o + A}{2}\right)}{\sin\left(\frac{A}{2}\right)}$$

and A is constant for the same prism but the refractive index (n) changes by changing the wavelength of the used light, so the angle of minimum deviation changes with the wavelength.

(2) Because the angle of deviation depends on the refractive index of the prism for the light color which is inversely proportional to the wavelength of the color and the wavelength of violet light is less than the wavelength of red light, hence the angle of deviation of violet light is larger than that of the red light.

(3) Because the angle of deviation depends on the wavelength, so as each color has different wavelength, light emerges separated from the prism while the cuboid works as two inverted prisms where they cancel the effect of each other.

3 (1) $n = \frac{\sin\left(\frac{\alpha_o + A}{2}\right)}{\sin\left(\frac{A}{2}\right)}$

- The apex angle of the prism (A).
- The refractive index of the prism material of the used light (n).
- The wavelength of the used light ($\lambda$).

(2) $\alpha_o = A(n - 1)$

- The apex angle of the prism (A).
- The refractive index of the prism material (n) for the used light.

(3) $\left((\alpha_o)_b - (\alpha_o)_r = A(n_b - n_r)\right)$

- The apex angle of the prism (A).
- The refractive indices for both blue and red light colors.

(4) $\left(\omega_\alpha = \frac{n_b - n_r}{n_y - 1}\right)$

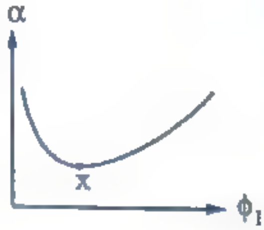
- The refractive index of the prism.

4 (a) The angle of minimum deviation ($\alpha_o$).

(b) The apex angle of the prism (A).

(c) – A

5 When the angle of incidence of the light ray increases, the angle of deviation decreases gradually till it reaches a definite value at point x which is the minimum value of deviation angle,




after that when the angle of incidence ($\phi_1$) increases, the angle of deviation increases gradually again.

## Answers of New Types of questions

### First Choose two correct answers

1 ⓒ the apex angle of the prism is 60°

ⓓ the angle of deviation of the ray equals 30°

2 ⓐ the slope of the graph line equals the apex angle of the prism

ⓒ the quotient of $\frac{y}{x}$ equals the apex angle of the prism

### Second Put in front of each of the following sentences the light color that makes the magnitude of the physical quantity greater

(1) Red light (2) Blue light (3) Blue light

(4) Blue light (5) Red light (6) Blue light

## Answers of Test on Chapter 2

### First Choose the correct answer

1 ⓐ increases by 20°
2 ⓓ ab
3 ⓑ
4 ⓓ 400 nm
5 ⓑ Light dispersion
6 ⓒ $\frac{x}{3.5}$
7 ⓒ $2.12 \times 10^8$ m/s
8 ⓑ 1.5
9 ⓓ 60°
10 ⓒ 60°

### Second Answer the following questions

11 Because the refractive index for any transparent medium is determined from the relation; $n = \frac{c}{v}$ and as the speed of light in space (c) is always greater than its speed in any other medium (v), so the refractive index of any medium is always greater than one.

12 The wavelength of light in the phenomenon of diffraction doesn't change since light remains travelling in the same medium.

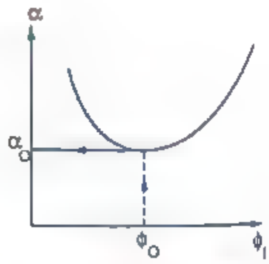
13 When light falls on the internal surface of the glass cube, light rays get refracted away from the normal and as getting away from the center opposite the light source on the glass surface the angle of refraction increases till it becomes 90°, then after that the falling rays undergo total internal reflection inside the cube leading to the formation of circular spots on the lateral screens around the cube.

14 The dispersive power doesn't change as it depends only on the refractive index of the prism material and not on the angle of incidence.

15 By increasing the separating distance between the double-slit barrier and the observation screen with the same rate of which the wavelength of the light decreases.

16 Material B has to be used in the core and A in the external layer because total internal reflection is achieved only when the core has higher optical density than the external layer.

17 The angle of deviation will decrease until it reaches a minimum value ($\alpha_o$) then it will increase again as the opposite graph :




## Answers of Accumulative Test on Chapters 1 & 2

### First Choose the correct answer

1 ⓒ $\frac{9}{9}$

2 ⓒ $\frac{1}{3}$ Hz

3 ⓒ Second bright fringe

4 ⓓ Their pattern shifts

5 ⓑ $1.5 \times 10^8$ m/s

6 ⓐ 0.3 mm

7 ⓓ 33 m

8 (c) 0.03

9 (d) $\mu_s = \mu_1$

10 (b) $10.2^\circ$

## Second Answer the following questions

11 The speed of light (c) $= 3 \times 10^8$ m/s

The time taken by light to reach the first man $t_1$ :

$$t_1 = \frac{8 \times 10^3}{3 \times 10^8} = 2.6 \times 10^{-5}\ s$$

The time difference between the two watches :

$\Delta t = 3\,s$

$(t_s) = \Delta t - t_1 = 2.99997\,s$

The distance between the second man and the tower (d) $= 360 \times 2.99997 = 1079.99$ m

The watch of the first man is more accurate despite that the man is farther from the tower but the speed of light is very high compared to the speed of sound.

12 (a) $N = 7 - 2 = 5\ ,\ \lambda = \frac{20}{5} = 4\ m$

(b) $N = 5 - 1 = 4\ ,\ T = \frac{0.1}{4} = 0.025\ s\ ,\ \upsilon = 40\ Hz$

(c) $v = \frac{\lambda}{T} = \lambda\,\upsilon = 4 \times 40 = 160$ m/s

13 $n = \frac{\sin\phi}{\sin\theta} = \frac{\sin 45^\circ}{\sin\theta} = 1.33$

$\sin\theta = \frac{\sin 45^\circ}{1.33}$

$\therefore \theta = 32.11^\circ$

The angle with the surface $= 90 - 32.11 = 57.89^\circ$

The angle between the reflected and the refracted

$= 57.89 + 45 = 102.9^\circ$

14 (a) $n = \frac{c}{v}\ ,\ v = \frac{c}{n} = \frac{3 \times 10^8}{1.5} = 2 \times 10^8$ m/s

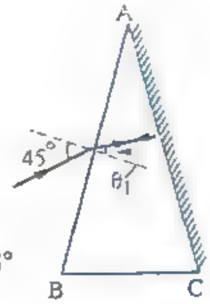
(b) The frequency in glass is the same as in air.

$$\upsilon = \frac{c}{\lambda} = \frac{3 \times 10^8}{5 \times 10^{-7}} = 6 \times 10^{14}\ Hz$$

15 $A = \theta_1 + 0 \Rightarrow \theta_1 = 30^\circ$

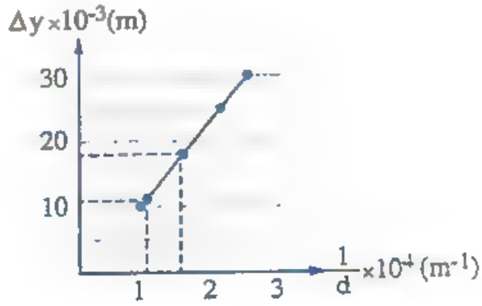
$$\therefore n = \frac{\sin\phi_1}{\sin\theta_1}$$

$$= \frac{\sin 45}{\sin 30} = \sqrt{2}$$




16 $A = \frac{\alpha_o}{(n-1)} = \frac{2^\circ}{\left(\frac{1.5}{1.2} - 1\right)} = \frac{2}{0.25} = 8^\circ$

17 (a)




(b) 1- $a = 1.5\ (10^4\ m^{-1})$

$, b = 11\ (10^{-3}\ m)$

2- Slope $= \lambda R$

$$= \frac{(30 - 10) \times 10^{-3}}{(2.5 - 0.9) \times 10^4}$$

$= 12.5 \times 10^{-7}$

$$\lambda = \frac{\text{Slope}}{R} = \frac{12.5 \times 10^{-7}}{2} = 6.25 \times 10^{-7} m$$

# Answers of Unit Two

## Chapter 4 Lesson One

### First Multiple choice questions

1 (c) equal to one

2 (a) increases

3 (a) mass

4 (a) the liquid speed at that point

5 (c) remains constant

6 (a) the liquid speed

7 (d) the liquid density

8 (c) 0.02 m/s

$$Q_m = \rho A v$$

$$v = \frac{Q_m}{\rho A} = \frac{10}{1000 \times 0.5}$$

$$= 0.02 \text{ m/s}$$

9 (i) (c) 0.0942 $m^3$

$$V_{ol} = Avt = \pi r^2 vt$$

$$= 3.14 \times 10^{-4} \times 5 \times 60 = 0.0942 \text{ m}^3$$

(ii) (b) 212.31 minutes

$$t = \frac{V_{ol}}{Q_v} = \frac{V_{ol}}{Av}$$

$$= \frac{20}{3.14 \times 10^{-4} \times 5} = 12738.85 \text{ s}$$

$$= 212.31 \text{ minutes}$$

10 (i) (d) 4 m/s

$$A_1 v_1 = A_2 v_2 \quad , \quad 4 \times 2 = 2 v_2 \quad , \quad v_2 = 4 \text{ m/s}$$

(ii) (c) $8 \times 10^{-4}$ $m^3/s$

$$Q_v = A_1 v_1 = 4 \times 10^{-4} \times 2 = 8 \times 10^{-4} \text{ m}^3/\text{s}$$

(iii) (b) 0.8 kg/s

$$Q_m = \rho Q_v = 1000 \times 8 \times 10^{-4} = 0.8 \text{ kg/s}$$

11 (c) $10.8 \times 10^3$ kg

12 (b) 0.4 cm

$$A_1 v_1 = A_2 v_2 \quad , \quad d_1^2 v_1 = d_2^2 v_2$$

$$(1.2)^2 \times 3 = d_2^2 \times 27 \quad , \quad d_2 = 0.4 \text{ cm}$$

13 (b) $Q_m$

14 d

15 a, 1 m/s

$$A_1 v_1 = A_2 v_2 \quad , \quad r_1^2 v_1 = r_2^2 v_2$$

$$r^2 \times 4 = (2r)^2 v_2 \quad , \quad v_2 = 1 \text{ m/s}$$

16 c $2.5 \times 10^{-5}$ $m^2$

$$Q_v = Av$$

$$\frac{6 \times 10^{-3}}{60} = A \times 4 \quad , \quad A = 2.5 \times 10^{-5} \text{ m}^2$$

17 a 0.01 $m^3/s$, 10 m/s

$$Q_v = \frac{V_{ol}}{\Delta t} = \frac{18}{30 \times 60} = 0.01 \text{ m}^3/\text{s}$$

$$Q_v = Av \quad , \quad 0.01 = 10^{-3} v \quad , \quad v = 10 \text{ m/s}$$

18 b decreases to half its value

19 d $\frac{4}{1}$

20 d $\frac{\sqrt{5}}{1}$

$$\because v \propto \frac{1}{d^2} \qquad \therefore \frac{d_1^2}{d_2^2} = \frac{v_2}{v_1} = \frac{6}{1.2} = \frac{5}{1}$$

$$\frac{d_1}{d_2} = \frac{\sqrt{5}}{1}$$

21 c $\frac{1}{16}$

$$A_1 v_1 = A_2 v_2 \quad , \quad r_1^2 v_1 = r_2^2 v_2$$

$$\frac{v_1}{v_2} = \frac{r_2^2}{r_1^2} = \frac{\left(\frac{r}{4}\right)^2}{r^2} \quad , \quad \frac{v_1}{v_2} = \frac{1}{16}$$

22 (i) (d) 0.004 $m^3/s$

$$\text{Slope} = \frac{\Delta v}{\Delta\left(\frac{1}{A}\right)} = \frac{20 - 0}{(50 - 0) \times 10^2} = 0.004 \text{ m}^3/\text{s}$$

$$\text{Slope} = Q_v = 0.004 \text{ m}^3/\text{s}$$

(ii) (c) 7200 kg

$$m = Q_m \Delta t = \rho Q_v \Delta t$$

$$= 1000 \times 0.004 \times 30 \times 60 = 7200 \text{ kg}$$

23 (i) (c) 16.4 kg/s

$$Q_v = \frac{V_{ol}}{t} = \frac{1.2}{60} = \frac{1}{50} \text{ m}^3/\text{s}$$

$$Q_m = \rho Q_v = 820 \times \frac{1}{50} = 16.4 \text{ kg/s}$$

(ii) ⓑ 31.43 minutes

$$Q_v = \frac{(V_{ol})_{tank}}{t}$$

$$t = \frac{(V_{ol})_{tank}}{Q_v} = \frac{\pi r^2 h}{Q_v}$$

$$= \frac{\frac{22}{7} \times (2)^2 \times 3}{\frac{1}{50}} = 1885.71 \text{ s} = 31.43 \text{ minutes}$$

**24** ⓓ $\frac{4}{1}$

$$Q_m = \frac{\rho V_{ol}}{t} \quad , \quad \frac{(Q_m)_A}{(Q_m)_B} = \frac{\rho_A (V_{ol})_A t_B}{\rho_B (V_{ol})_B t_A}$$

Through the same time interval:

$$\frac{(Q_m)_A}{(Q_m)_B} = \frac{2 \times 2\,(V_{ol})_1}{1 \times (v_{ol})_1} = \frac{4}{1}$$

**25** ⓐ $\frac{9}{5}$

**26** ⓓ 3

**27** ⓓ $\rho_x < \rho_y < \rho_z$

**28** ⓑ 0.5 m

**29** ⓒ 0.6 $m^3$/s

**30** ⓐ 16 m/s

**31** ⓒ 1.6 m/s

**32** ⓑ 125

**33** ⓒ 0.032 m/s

$$A_1 v_1 = n A_2 v_2 \quad , \quad d_1^2 v_1 = n\, d_2^2 v_2$$

$$d_1^2 \times 0.24 = 120 \times \left(\frac{d_1}{4}\right)^2 \times v_2$$

$$v_2 = 0.032 \text{ m/s}$$

**34** ⓑ $\frac{v}{2}$

$$A_3 v_3 = A_1 v_1 + A_2 v_2$$

$$4\,Av_3 = Av + 2A\frac{v}{2}$$

$$4\,Av_3 = 2\,Av \quad , \quad v_3 = \frac{v}{2}$$

**35** (i) ⓑ 0.5652 $m^3$/s

$$Q_v = A_A v_A = \pi r_A^2 v_A$$

$$= 3.14 \times (30 \times 10^{-2})^2 \times 2 = 0.5652 \text{ m}^3/\text{s}$$

(ii) ⓒ 4.5 m/s

$$Q_v = A_B v_B$$

$$0.5652 = 3.14 \times (20 \times 10^{-2})^2 \times v_B$$

$$, v_B = 4.5 \text{ m/s}$$

(iii) ⓑ 7.5 m/s

$$Q_v = A_C v_C + A_D v_D + A_E v_E$$

$$0.5652 = 3.14 \times 10^{-4} \times \left((15^2 \times 3) + (10^2 \times v_D) + (5^2 \times 15)\right)$$

$$v_D = 7.5 \text{ m/s}$$

**36** ⓓ out of, 15 $cm^3$/s

$$(Q_v)_1 = (Q_v)_A + (Q_v)_B + (Q_v)_C + (Q_v)_E$$

$$= 6 + 3 + 5 + 4 = 18 \text{ cm}^3/\text{s}$$

$$(Q_v)_2 = (Q_v)_F = 3 \text{ cm}^3/\text{s}$$

$$\because (Q_v)_{in} = (Q_v)_{out}$$

$$\therefore (Q_v)_D = (Q_v)_1 - (Q_v)_2$$

$$= 18 - 3 = 15 \text{ cm}^3/\text{s}$$

And its direction is out of branch D

**37** ⓒ 30 minutes

$$Q_v = (Q_v)_1 + (Q_v)_2 + (Q_v)_3$$

$$\frac{V_{ol}}{t} = \frac{V_{ol}}{t_1} + \frac{V_{ol}}{t_2} + \frac{V_{ol}}{t_3}$$

$$\therefore \frac{1}{t} = \frac{1}{t_1} + \frac{1}{t_2} + \frac{1}{t_3}$$

$$\frac{1}{10} = \frac{1}{20} + \frac{1}{60} + \frac{1}{t_3}$$

$$\therefore t_3 = 30 \text{ minutes}$$

## Second Essay questions

**1** (a) Less than one.
(b) Equal to one.
(c) Equal to one.
(d) Less than one.

**2** **(1)** Because the density of streamlines indicates the flow speed of the liquid, so as the flow speed increases the streamlines density increases leading to more crowded streamlines.

**(2)** Because liquids are incompressible, so the amount of liquid entering the tube at one of its ends equals the amount of liquid that gets out from the other end of the tube through the same time interval.

**(3)** Because according to the continuity equation ($A_1 v_1 = A_2 v_2$), the liquid speed at any point inside the tube is inversely proportional to the cross-sectional area of the tube at that point ($v \propto \frac{1}{A}$).

**(4)** Because when the nozzle of the hose is directed downwards, water moves in the direction of gravity, hence its flow speed increases, so the cross-sectional area of water column decreases based on the continuity equation and when the

hose nozzle is directed upwards, water moves against the direction of gravity, hence its flow speed decreases and the cross-sectional area of water column increases due to the constant flow rate ($Q_v = Av$).

(5) Because according to the continuity equation ($A_1v_1 = A_2v_2$), the flow speed of a fluid is inversely proportional to the cross-sectional area of the tube, hence when the cross-sectional areas of the gas stove holes are small, the speed at which the gas rushes out from the openings becomes high.

3 To increase the flow speed of water at the nozzle of the hose, so the rushing out water from the hose can reach far distances at high flow speed that is adequate for pushing the sand away where the flow speed of water is inversely proportional to the cross-sectional area based on the continuity equation.

4 (1) Small eddy currents get formed due to the transformation of steady flow into turbulent flow.

(2) The flow speed of blood in the blood capillaries becomes less than its speed in the main artery based on the continuity equation ($A_1v_1 = nA_2v_2$), where the summation of the cross-sectional areas of blood capillaries is greater than the cross-sectional area of the main artery.

(3) The flow speed of the liquid at the end of the tube increases according to the continuity equation ($A_1v_1 = A_2v_2$).

## Answers of New Types of questions

### First Choose two correct answers

1 ⓒ cross-section x equals 2 v

ⓔ cross-section z equals 4 v

2 ⓑ the volume flow rate of the liquid from the pipe = $10^{-3}$ m$^3$/s

ⓓ the flow speed of the liquid through the pipe = 1 m/s

### Second Put in front of each of the following sentences the type of flow that it expresses

(1) Steady flow (2) Turbulent flow

(3) Turbulent flow (4) Steady flow

## Chapter 4 Lesson Two

### First Multiple choice questions

1 ⓑ the liquid viscosity

2 ⓓ remains constant

3 ⓐ increases

4 ⓐ

5 ⓐ the ball radius

6 ⓑ the frictional force between the swimmer and water

- When the swimmer dives in water, the direction of :

① his weight will be downwards.

② the frictional force between his body and water will be upwards.

③ the buoyant force of water will push him upwards.

- When the swimmer rises towards the surface of water, the direction of :

① his weight will be downwards.

② the frictional force between his body and water will be downwards.

③ the buoyant force of water will push him upwards.

∴ The force that changes its direction is the frictional force between the swimmer and water.

7 ⓓ $F_1 < F_2$

8 ⓑ increases

9 ⓒ greater than t because the viscosity of water is greater than that of air

10 ⓑ less than the average speed of ball y

11 ⓓ zero

12 ⓒ In glycerin

13 ⓐ x

14 ⓑ directly proportional to the speed of the car

15 ⓒ directly proportional to the square of the speed of the car.

16 ⓑ greater than Q

17 ⓓ 2.08 N.s/m$^2$

$$\eta_{vs} = \frac{Fd}{Av} = \frac{10 \times 5 \times 10^{-2}}{20 \times 40 \times 10^{-4} \times 3} = 2.08 \text{ N.s/m}^2$$

18 ⓐ 1.54 N

19 ⓒ 1.41 kg/m.s

20 ⓑ 2 F

21 ⓓ $\frac{8}{1}$

$$\because F = \eta_{vs} \frac{Av}{d}$$

$$\therefore v = \frac{Fd}{\eta_{vs} A}$$

$$\therefore \frac{v_x}{v_y} = \frac{d_x A_y}{d_y A_x} = \frac{2\,d \times (2\,\ell)^2}{d\,\ell^2} = \frac{8}{1}$$

22 ⓑ

23 ⓓ 53.33 N

$$F = \eta_{vs} \frac{Av}{d}$$

$$F_1 = 0.8 \times \frac{0.5 \times 2}{2 \times 10^{-2}} = 40 \text{ N}$$

$$F_2 = 0.8 \times \frac{0.5 \times 2}{6 \times 10^{-2}} = 13.33 \text{ N}$$

$$F = F_1 + F_2 = 40 + 13.33 = 53.33 \text{ N}$$

24 ⓑ $10^{-3}$ N

$$v = \frac{d}{t} = \frac{100\,x}{4} = (25\,x) \text{ m/s}$$

$$F = \eta_{vs} \frac{Av}{d}$$

$$= \frac{0.2 \times 2 \times 10^{-4} \times 25\,x}{x} = 10^{-3} \text{ N}$$

25 ⓐ $F_1 > F_2$

## Second Essay questions

**1** (1) Because close to the river bank, the frictional forces which resist the flow of water increase such that $(F \propto \frac{1}{d})$ and that decreases the probability of drifting away the aquatic plants due to the flowing water.

(2) Because as the moving layer (sea waves) gets closer to the static layer (shore), the frictional forces that impede the motion of waves increases, so the speed of the waves decreases.

(3) Because high floors are at large distances from the ground (static layer), the frictional forces that impede the motion of air layers decrease, hence the speed of airstream increases as the distance from the ground increases.

(4) Because the frictional forces between the liquid layers and the solid body increase.

(5) Due to the internal frictional forces between the layers of a liquid that reduce the speed of their motions gradually till they stop.

(6) Because as the distance between the moving layer fo a liquid (water stream) and the static layer (riverbed) increases, the forces that impede the motion of water decreases, hence the speed of water stream increases and the swimmer will need to exert more effort to overcome the speed of water stream.

(7) Because the viscosity of water is greater than that of air so that the forces that resist the motion of an object in water are greater than the forces that resist the motion of the same object in air.

(8) To decrease the generated heat due to friction between the parts of the machine when it is operated and to protect its parts from corrosion.

(9) Because the viscosity of liquids decreases as temperature increases.

(10) Because fluids of high viscosity remain attached to the machine parts and do not sweep away or sputter from the machine parts during their motion, hence the generated heat due to the friction between the machine parts gets reduced and the parts are protected from corrosion.

(11) Because water has low viscosity, so it sweeps away and sputter from the machine parts during their motion due to its weak adhesive forces with them.

**(12 : 14) Answer by yourself.**

**2** (1) The required tangential force increases to the double because ($F \propto A$).

(2) The viscosity of the liquid increases.

(3) High amount of heat gets generated due to friction during operation that leads to machine parts' corrosion.

(4) The fuel consumption rate of the car increases because the resistance of air to the car motion becomes directly proportional to the square of the speed of the car at high speeds.

3 Because as the moving layer gets closer to the static layer, the frictional forces due to viscosity increase, hence the speed decreases and the speed of water at the middle of the river stream becomes higher than its speed close to the river bank, so:

- During sailing from Aswan to Cairo the ship is moving in the same direction of the water currents of the Nile, so the captain sails the ship in the middle of the river stream to move faster.
- During sailing from Cairo to Aswan the ship is moving against the direction of the water currents of the Nile, so the captain sails the ship closer to the river bank where the water resistance to the motion of the ship becomes small.

4 The submarine needs a greater force to push it inside water.

## Answers of New Types of questions

### First Choose two correct answers

1 ⓐ, ⓑ

2 ⓒ the liquid viscosity coefficient remains unchanged

ⓓ the velocity difference between the two plates increases

### Second From the shown figure answer the following

(1) No change (2) Decrease

(3) No change (4) No change

## Answers of Test on Chapter 4

### First Choose the correct answer

1 ⓒ $\frac{9}{4}$

2 ⓑ

3 ⓓ the speed of the liquid at z equals its speed at y

4 ⓐ $\frac{1}{7}$ hour

5 ⓒ 28.5 N

6 ⓓ remains constant

7 ⓑ 0.016 $m^3/s$

8 ⓑ Ball B

9 ⓓ 0.4 $m^3/s$

10 ⓑ 900 kg

### Second Answer the following questions

11 The flow of the liquid becomes turbulent.

12 $Q_v = Av$

$10^{-8} = 0.1 \times 10^{-6}\, v$

$v = 0.1$ m/s

13 Viscosity of d > That of b > That of a > That of c because after 2 s the ball moved a distance through liquid d less than b and in b less than a and in a less than c.

14 The flow speed of the liquid gets higher at the narrower section which is section B according to the continuity equation $A_1v_1 = A_2v_2 = A_3v_3$, so as the cross-sectional area of the tube decreases, the flow speed increases.

15 Because viscosity decreases as temperature increases so in summer a higher viscous oil is better for the engine.

16 The best way to save the fuel is by reducing the car speed to reduce the resistance of air to the car motion because at higher speeds the air resistance due to viscosity gets proportional to the square of the car speed which leads to a higher consumption of the fuel.

17 $A_1v_1 = n\,A_2v_2$

$r_1^2v_1 = n\,r_2^2v_2$

$n = \frac{r_1^2v_1}{r_2^2v_2}$

$= \frac{(1.2)^2 \times 40 \times 10^{-2}}{(4 \times 10^{-4})^2 \times 5 \times 10^{-4}} = 7.2 \times 10^9$ capillaries

## Answers of Accumulative Test on Chapters 1, 2 & 4

### First Choose the correct answer

1 ⓑ halved

2 ⓑ 100°

3 ⓑ 44.7 cm

4 ⓒ 703 $kg/m^3$

**5** ⓑ 751 m

The speed of sound in the track ($v_s$)
$= 20\ v_a$ (in air)

$t_a$ (time in air) $= t_s$ (in the track) $+ \Delta t$

$v_s = 20\ v_a$

$\frac{X}{t_s} = 20\frac{X}{t_a} = \frac{20X}{t_s + \Delta t}$

$\frac{t_s + \Delta t}{t_s} = \frac{20X}{X}$

$1 + \frac{\Delta t}{t_s} = 20$

$\Delta t = 19\ t_s$

$t_s = \frac{\Delta t}{19} = \frac{2.1}{19} = 0.11\text{s}$

$t_a = t_s + \Delta t = 2.1 + 0.11 = 2.21$

$X = v_a t_a = 340 \times 2.21 = 751$ m

**6** ⓒ $\frac{2}{3}$ **7** ⓒ 36 minutes

**8** ⓑ 1.58 **9** ⓓ 0.375 μm

**10** ⓒ increase

## Second Answer the following questions

**11** The angle of incidence $\phi_1 = 90 - \theta_1$
$= 90° - 49° = 41°$

$n_1 \sin\phi_1 = n_2 \sin\phi_2$

$1.4 \sin 41 = 1.2 \sin\phi_2$

$\phi_2 = 49.94°$

$n_2 \sin\phi_2 = n_3 \sin\phi_3$

$1.2 \sin 49.94 = \sin\phi_3$

$\phi_3 = 66.7°$

$\theta_2 = 90 - \phi_3 = 23.3°$

**12** $\Delta y = \frac{\lambda R}{d} = \frac{547 \times 10^{-9} \times 0.9}{1.5 \times 10^{-3}} = 0.33$ mm

$W = 5\Delta y = 1.64$ mm

**13** - For the longest wavelength :

$\sin\theta_1 = \frac{\sin\phi_1}{n} = \frac{\sin 55}{1.517}$

$\theta_1 = 32.7°$ , $\phi_2 = A - \theta_1$

$\phi_2 = 60 - 32.7 = 27.32°$

$\sin\theta_2 = n \sin\phi_2 = 1.517 \sin 27.32$

$\theta_2 = 44.13°$

- For the shortest wavelength :

$\sin\theta_1 = \frac{\sin\phi_1}{n} = \frac{\sin 55}{1.538}$

$\theta_1 = 32.18°$

$\phi_2 = 60 - 32.18° = 27.82°$

$\sin\theta_2 = n \sin\phi_2 = 1.538 \sin 27.82$

$\theta_2 = 45.87$

∴ The range of refraction angles is from 44.13° for the longest visible wavelengths to 45.87 for the shortest visible wavelengths.

**14** $Q_1 = \frac{(V_{ol})_1}{\Delta t_1} = A_1 v_1$ , $A_1 = \pi\left(\frac{1}{2}d_1\right)^2$

$Q_2 = \frac{(V_{ol})_2}{\Delta t_2} = A_2 v_2$ , $A_2 = \pi\left(\frac{1}{2}d_2\right)^2$

$(V_{ol})_1 = L = \pi\left(\frac{1}{2}d_1\right)^2 v_1 \Delta t_1$ ①

$(V_{ol})_2 = 3L = \pi\left(\frac{1}{2}d_2\right)^2 v_2 \Delta t_2$ ②

From ① and ② :

$L = \pi\left(\frac{1}{2}d_1\right)^2 v\Delta t_1$ ③

$3L = \pi\left(\frac{1}{2}d_2\right)^2 2v\Delta t_1$ ④

Divide ③ by ④ :

$\frac{1}{3} = \frac{d_1^2}{2d_2^2}$

$\frac{d_1}{d_2} = \sqrt{\frac{2}{3}}$

**15** (a) $(\alpha_o)_b - (\alpha_o)_r = A(n_b - n_r)$
$= 7(1.66 - 1.55) = 0.77°$

(b) $(\alpha_o)_r = 7(0.55) = 3.85$

$(\alpha_o)_b = 7(0.66) = 4.62$

**16** (a) $\sin(90 - \theta_1) = \frac{\sin(90 - 30)}{1.35}$

$\theta_1 = 50.1°$

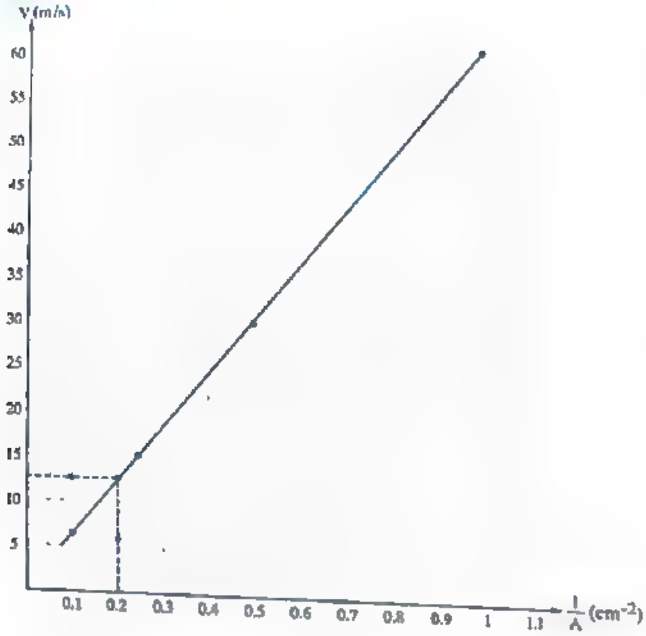
(b) $\sin\phi_c = \frac{1}{n} = \frac{1}{1.35}$

$\phi_c = 47.8°$

(c) It will follow path A because the angle of incidence is greater than $\phi_c$ ($\theta_1 > \phi_c$).

(d) $\theta_A = 90 - \theta_1 = 90 - 50.1 = 39.9°$

**17** (a)




(b) 1- At 5 cm$^2$ , $\frac{1}{A} = 0.2$

$v = 12$ m/s

2- $Q_v = Av = 60 \times (1 \times 10^{-2})^2 = 6 \times 10^{-3}$ m$^3$/s

**Second** Answers of Test Yourself Questions

## Chapter 1 Lesson One

**1** [1] ⓓ double the time of motion from z to x

[2] ⓑ 0, 4 A [3] ⓓ

**2**

[1] ⓒ the kinetic energy at y = The kinetic energy at k

- The kinetic energy at point z has the maximum value and it decreases gradually with moving away from the equilibrium position.

$\therefore (KE)_z > (KE)_y = (KE)_k > (KE)_x = (KE)_\ell$

- The potential energy of the pendulum bob at x and $\ell$ has the maximum value and it decreases gradually with approaching the equilibrium position.

$\therefore (PE)_x = (PE)_\ell > (PE)_y = (PE)_k > (PE)_z$

$\therefore$ The answer is ⓒ the kinetic energy at y = The kinetic energy at k

[2] ⓒ $\frac{(PE)_b}{(PE)_d}$

## Chapter 1 Lesson Two

**1** [1] (a) $T = \frac{t}{N} = \frac{12}{2} \times 10^{-3} = 6 \times 10^{-3}$ s

(b) $\upsilon = \frac{N}{t} = \frac{2}{12} \times 10^3 = 166.67$ Hz

**Or:**

$\upsilon = \frac{1}{T} = 166.67$ Hz

(c) $\lambda = \frac{x}{N} = \frac{35}{1.25} = 28$ cm

[2] (i) ⓒ 2 e (ii) ⓓ $\frac{1}{2}$ b

(iii) ⓑ increasing distance a to the double

**2** [1] (1) Transverse wave.

(2) Longitudinal wave.

[2] ⓓ $\frac{3}{1}$

**3** [1] ⓓ $\frac{2}{3}$

$\because v = \lambda\,\upsilon \qquad \therefore \frac{v_1}{v_2} = \frac{\lambda_1}{\lambda_2}$

$\therefore \frac{v_1}{v_2} = \frac{2}{3}$

[2] ⓒ $\frac{1}{1}$

$\because$ The two waves are sound waves (same type) and they propagate in air (same medium).

$\therefore$ They have the same speed.

$\therefore$ The speed of the sound of the man ($v_{man}$) is the same as the speed of the sound of the girl ($v_{girl}$).

$\therefore \frac{v_{man}}{v_{girl}} = \frac{1}{1}$

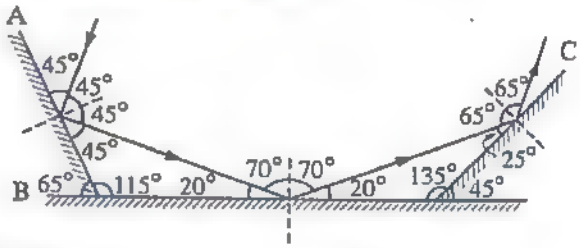
[3] ⓓ Doesn't change, Decreases.

[4] ⓓ

## Chapter 2 Lesson One

**1**

[1] Applying the laws of light reflection and according the geometry of the figure:




[2] (1) ⓒ C (2) ⓐ will increase

**2** ⓐ $\because {}_1n_2 = \frac{\sin\phi}{\sin\theta} = \frac{\lambda_1}{\lambda_2}$

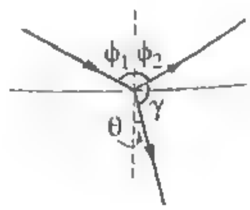
$\because \lambda_1, \phi$ are constants.

$\therefore \lambda_2 \propto \theta$

$\therefore$ Light rays in medium x has the longest wavelength.

$\therefore$ The correct answer is ⓐ.

**3** [1] $\phi_1 = \phi_2 = 60°$




$n = \frac{\sin\phi_1}{\sin\theta}$

$1.5 = \frac{\sin 60}{\sin\theta}$

$\theta = 35.26°$

$\gamma = 180 - (\phi_2 + \theta)$

$= 180 - (60 + 35.26) = 84.74°$

[2] $\phi = 90 - 30 = 60°$

$n = \frac{\sin\phi}{\sin\theta}$

$\sqrt{3} = \frac{\sin 60}{\sin\theta}$

$\theta = 30°$

From the geometry of the shape:

$\tan\theta = \frac{1}{l}$

$l = \frac{1}{\tan\theta} = \frac{1}{\tan 30} = \sqrt{3}$ cm

[3] (1) ⓑ $2 \times 10^8$ m/s

(2) ⓒ increases by a value smaller than 5°

(3) ⓑ will decrease

## Chapter 2 Lesson Two

**1**

[1] $\Delta y = \frac{\lambda R}{d}$

$= \frac{66 \times 10^{-8} \times 1}{11 \times 10^{-4}}$

$= 6 \times 10^{-4}$ m

[2] (1) ⓑ 0.75 mm (2) ⓑ

**2** ⓒ

## Chapter 2 Lesson Three

**1** [1] $\sin\phi_c = \frac{n_{water}}{n_{glass}} = \frac{\lambda_{glass}}{\lambda_{water}} = \frac{5000}{5625}$

$\therefore \phi_c = 62.73°$

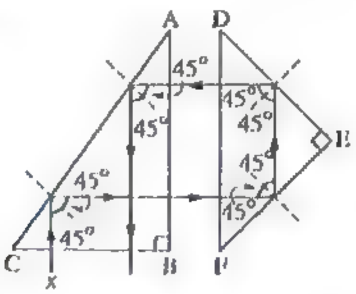
[2] $\sin\phi_c = \frac{n_{oil}}{n_{glass}} = \frac{\frac{1}{\sin(\phi_c)_{oil}}}{\frac{1}{\sin(\phi_c)_{glass}}}$

$= \frac{\sin(\phi_c)_{glass}}{\sin(\phi_c)_{oil}} = \frac{\sin 41.81}{\sin 43.23}$

$\therefore \phi_c = 76.74°$

[3] (1) ⓑ Angle (2) (2) ⓑ $v_1 > v_3 > v_2$

**2** [1] ⓓ BC




$\therefore$ Light ray x emerges from face BC.

$\therefore$ The correct answer is ⓓ.

[2] ⓐ 0.6

## Chapter 2 Lesson Four

[1] $\theta_1 = 90 - 60 = 30°$

$\phi_2 = 90 - 65 = 25°$

$A = \theta_1 + \phi_2 = 30 + 25 = 55°$

$n = \frac{\sin\phi_1}{\sin\theta_1}$

$1.5 = \frac{\sin\phi_1}{\sin 30}$

$\therefore \phi_1 = 48.59°$

$n = \frac{\sin\theta_2}{\sin\phi_2}$

$1.5 = \frac{\sin\theta_2}{\sin 25}$

$\therefore \theta_2 = 39.34°$

$\alpha = \phi_1 + \theta_2 - A$

$= 48.59 + 39.34 - 55 = 32.93°$

[2] (1) ⓐ decreases (2) ⓐ decreases

## Chapter 2 Lesson Five

**1** ⓓ

**2** [1] $n = \frac{\sin\left(\frac{\alpha_o + A}{2}\right)}{\sin\left(\frac{A}{2}\right)}$

$1.5 = \frac{\sin\left(\frac{\alpha_o + 60}{2}\right)}{\sin\left(\frac{60}{2}\right)}$

$\sin\left(\frac{\alpha_o + 60}{2}\right) = \frac{3}{4}$

$\therefore \alpha_o = 37.18°$

[2] ⓒ 60° [3] Yes

**3** [1] ⓓ All of them have the same deviation angle

[2] ⓒ 1, 8

**4** [1] $(\alpha_o)_b - (\alpha_o)_r = A(n_b - n_r)$

$= 10(1.58 - 1.52)$

$= 0.6°$

$n_y = \frac{n_b + n_r}{2} = \frac{1.58 + 1.52}{2} = 1.55$

$\omega_\alpha = \frac{n_b - n_r}{n_y - 1} = \frac{1.58 - 1.52}{1.55 - 1} = 0.11$

[2] ⓑ $\omega_\alpha$

## Chapter 4 Lesson One

1 The statement is not true.

∵ The number of streamlines is constant through the same tube.

∴ The streamlines density at terminal y is greater than its density at terminal x.

∴ The speed of flow at y is higher than the speed of flow at x.

2

[1] $Q_v = Av$

$= \pi r^2 v$

$= \frac{22}{7} \times (2 \times 10^{-2})^2 \times 1$

$= 1.26 \times 10^{-3}\ m^3/s$

$Q_m = Q_v \rho$

$= 1.26 \times 10^{-3} \times 1000$

$= 1.26\ kg/s$

[2] (1) ⓓ increases to 16 times its original value

(2) ⓓ 5 V

(3) ⓑ $10^{-3}\ m^3/s$

## Chapter 4 Lesson Two

[1] It is better to design ships that have small bottom areas because the resistance force due to viscosity is directly proportional to the area of the moving layer, hence as the area of contact between the ship bottom and water decreases the force of viscosity decreases.

[2] (1) ⓒ $\frac{2}{d}$

(2) ⓑ At point B

(3) ⓓ $\frac{4}{1}$

# Third | Answers of General Exams

## Answer of General Exam 1

### First Choose the correct answer

1. (d) 0.36°
2. (a) $\sqrt{2}$
3. (c) 0.1, 0.5
4. (c) 0.04 $m^2$
5. (d) 4 v
6. (d) $\sqrt{3}$
7. (c) $\frac{4}{7}$
8. (a) greater than 1
9. (d) 1 m/s, 2 m/s
10. (a) 10 Hz
11. (d) 633 nm
12. (b) point b
13. (d) Cylinder 4
14. (d) 0
15. (d) mechanical waves
16. (a) greater than 1
17. (d) increases in area
18. (a) 1
19. (d) $\frac{1}{4} Q_V$
20. (c) 0.2
21. (c) 1.35

### Second Answer the following questions

22. $\because \alpha_o = A\left(\frac{n_2}{n_1} - 1\right)$ $\therefore \alpha_o = 8\left(\frac{1.5}{\frac{4}{3}} - 1\right)$

$\therefore \alpha_o = 1°$

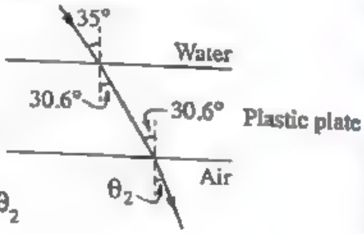
23. Because of the viscosity of air, the air layers which is closer to the ground move slower than the layers which are at high distances from the ground.

24. - From water to the plastic plate:

1.33 sin 35°

= 1.5 sin $\theta_1$

$\therefore \theta_1 = 30.6°$




- From plastic plate to air:

1.5 sin 30.6 = sin $\theta_2$

$\therefore \theta_2 = 49.7°$

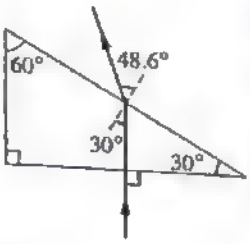
**Another Solution :**

1.33 sin 35° = sin $\theta_2$

$\theta_2 = 49.7°$

25. 1.5 sin 30 = sin θ

$\therefore \theta = 48.6°$




26. - Wave A:

$v_A = \frac{X_A}{t_A} = \frac{60 \times 10^{-2}}{0.3 \times 10^{-3}} = 2000$ m/s

- Wave B:

$v_B = \frac{X_B}{t_B} = \frac{60 \times 10^{-2}}{0.3 \times 10^{-3}} = 2000$ m/s

27. (a) $\because (\sin \phi_c)_1 = \frac{n_{air}}{n_{water}}$ $\therefore \sin 48 = \frac{1}{n_{water}}$

$\therefore n_{water} = 1.34$

$\because (\sin \phi_c)_2 = \frac{n_{air}}{n_{oil}}$ $\therefore \sin 44 = \frac{1}{n_{oil}}$

$\therefore n_{oil} = 1.44$

$\therefore {}_w n_o = \frac{n_{oil}}{n_{water}} = \frac{1.44}{1.34} = 1.07$

(b) $\because \sin \phi_c = \frac{n_{water}}{n_{oil}}$ $\therefore \sin \phi_c = \frac{1.34}{1.44}$

$\therefore \phi_c = 68.52°$

## Answer of General Exam 2

### First Choose the correct answer

1. (b) 2.24 m/s
2. (a) 1
3. (c) 1.7
4. (d)
5. (b) 7.5
6. (c) θ
7. (d) 68.4 m
8. (b) $\frac{5}{2}$
9. (d) 1.5 d
10. (a) 1.33
11. (d) 37.8°
12. (b) refracts toward the normal
13. (d) 225
14. (c) 6 s
15. (d) 99.3°
16. (b) 45°
17. (b) always dark
18. (b) the source frequency
19. (a) greater than 1
20. (d) the refraction coefficient of the prism
21. (d) totally reflects

### Second Answer the following questions

22. To decrease the heat produced due to friction, to protect the machine parts from corrosion and to increase their efficiency.

23. $\because \Delta y = \frac{\lambda R}{d}$ $\therefore d = \frac{\lambda R}{\Delta y}$

$\therefore d = \frac{575 \times 10^{-9} \times 2.75}{2.75 \times 10^{-3}} = 575\ \mu m = 5.75$ mm

24. $\because$ Momentum = Mass × Velocity

$\because$ The viscosity of water is greater than that of air.

$\therefore$ The velocity of the body decreases more quickly when it moves in water than in air.

$\because$ momentum $\propto$ velocity

$\therefore$ The momentum of the body also decreases in water more quickly than in air.

**25** (a) $\sin 45 = \sqrt{2} \sin \theta_1$ , $\theta_1 = 30°$

$\because \sqrt{2} \sin 30 = \sin \theta_2$ $\therefore \theta_2 = 45°$

(b) $\because \alpha = \phi_1 + \theta_2 - A$ $\therefore \alpha = 45 + 45 - 60 = 30°$

**26** (a) $A = \frac{60 - 10}{2} = 25$ cm

(b) $d = 2 \times 4 \times 25 = 200$ cm

**27** The light will emerge to the water because its angle of incidence is less than the critical angle between water and glass, where:

$\sin \phi_c = \frac{n_w}{n_g}$ , $\sin \phi_c = \frac{1.33}{1.58}$

$\therefore \phi_c = 57.3°$

## Answer of General Exam 3

### First Choose the correct answer

1. (a) $\frac{R}{1.5}$
2. (a) $\frac{5}{6}$
3. (d) $2.8\ N.s/m^2$
4. (d) 844.8 cm
5. (d) 80°, 1.35
6. (c) 46.89°
7. (a) decreases
8. (a) increases
9. (c) The amplitude = The distance between z and y
10. (b) 5, 0.2
11. (a) 0.2 m/s
12. (c) 50°
13. (b) row with a greater force
14. (b) 1
15. (a) greater than A
16. (b) It gets reflected because the angle of incidence is greater than the critical angle between the two media
17. (d) remains constant
18. (b) The diffraction happens when light propagates in the same medium and the refraction happens when light transfers from one medium to another
19. (c) frequency
20. (d) 471 kg
21. (d) all the previous

### Second Answer the following questions

**22** $\because n_1 \sin \phi_1 = n_2 \sin \theta_1$

$\because \phi_2 = \theta_1$

$\therefore n_2 \sin \phi_2 = n_1 \sin \theta_2$

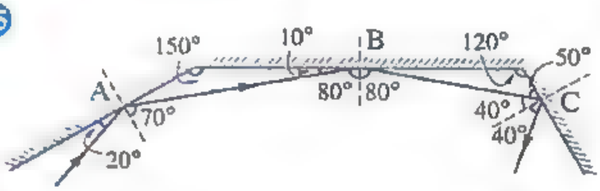
$\therefore \theta_2 = \phi_1 = 45°$

**23** $\because$ The wavelength of red light is greater than that of blue light and as $\Delta y \propto \lambda$

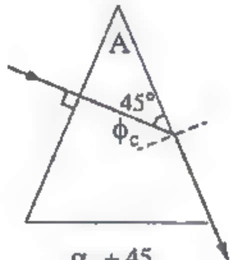
$\therefore$ The interference fringes will be more separated and noticeable.

**24** The vibrational motion is considered a periodic motion because the body vibrates and repeats its motion in regular time intervals, but not every periodic motion is considered a vibrational motion as the motion of the Moon around Earth where it repeats itself in regular time intervals but it is not considered a vibrational motion.

**25**




**26** $\because \sin \phi_c = \frac{1}{\sqrt{2}}$




$\therefore \phi_c = 45°$

$\therefore A = 45°$

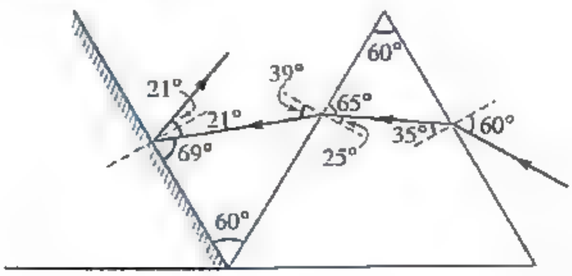
At minimum deviation:

$$n = \frac{\sin\left(\frac{\alpha_o + A}{2}\right)}{\sin\left(\frac{A}{2}\right)} \qquad \therefore \sqrt{2} = \frac{\sin\left(\frac{\alpha_o + 45}{2}\right)}{\sin\left(\frac{45}{2}\right)}$$

$$\therefore 32.8° = \frac{\alpha_o + 45}{2} \qquad \therefore \alpha_o = 20.5°$$

$$\because \phi_1 = \theta_2 = \frac{\alpha_o + A}{2} \qquad \therefore \phi_1 = \frac{20.5 + 45}{2} = 32.8°$$

**27** Angle of reflection from the surface of the mirror = 21°



## Answer of General Exam 4

### First Choose the correct answer

1. (b) $50°$
2. (b) 0.625 N
3. (c) $59.36°$
4. (a) $\upsilon_A < \upsilon_B$
5. (d) 650 nm
6. (c) $T_1 > T_2 > T_3$
7. (c) remains constant
8. (b) $45°$
9. (b) $6.74 \times 10^{-3}$ m/s
10. (b) 1.5
11. (a) $0.11\ m^2$
12. (d) 1
13. (c) 1.62
14. (c) yellow
15. (a) 1.5
16. (c) Constant, Constant
17. (b) gets refracted away from the normal line
18. (b) $40°$
19. (b) $\phi = \theta = 0°$
20. (c) $60°$
21. (c) increases, decreases

### Second Answer the following questions

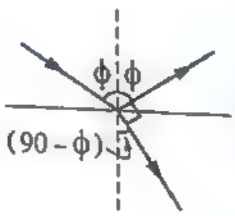
22. $\theta = 90 - \phi$

$\sin \phi = n \sin (90 - \phi)$

$\sin \phi = 1.55 \cos \phi$

$\tan \phi = 1.55$

$\phi = 57.17°$




23. $\because$ Amplitude $= 10 - 7 = 3$ cm

$\therefore$ The distance covered in complete vibration $= 3 \times 4 = 12$ cm

$\therefore$ The distance covered during five complete vibrations $= 12 \times 5 = 60$ cm

24. Because the angle of minimum deviation is defined from :

$$n = \frac{\sin\left(\frac{\alpha_\circ + A}{2}\right)}{\sin\left(\frac{A}{2}\right)}$$

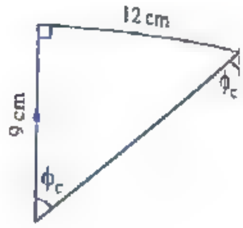
and A is constant for the same prism but the refractive index (n) changes by changing the wavelength of the used light, so the angle of minimum deviation changes with the wavelength.

25. $\because \tan \phi_c = \frac{12}{9} = \frac{4}{3}$

$\therefore \phi_c = 53°$

$\therefore n = \frac{1}{\sin \phi_c}$

$= \frac{1}{\sin 53} = 1.25$




26. (a) $v = \frac{d}{t} = \frac{136}{0.4} = 340$ m/s

(b) $d = \frac{1}{2}\lambda = \frac{1}{2} v T = \frac{1}{2}(340 \times 4 \times 10^{-3}) = 0.68$ m

27. $\Delta y = \frac{\lambda R}{d}$

$6 \times 10^{-3} = \frac{\lambda \times 100 \times 10^{-2}}{8 \times 10^{-5}}$

$\lambda = 4.8 \times 10^{-7}$ m

$\therefore \upsilon = \frac{c}{\lambda} = \frac{3 \times 10^8}{4.8 \times 10^{-7}} = 6.25 \times 10^{14}$ Hz

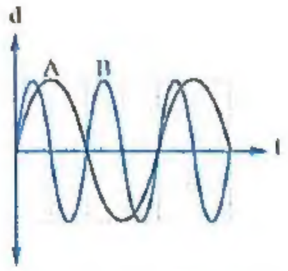
## Answer of General Exam 5

### First Choose the correct answer

1. (b)
2. (c) equal to 1
3. (d) 4 mm
4. (d) $\frac{4}{1}$
5. (c) 30 cm/s
6. (b) greater than 1
7. (d) 2
8. (c) 100 Hz
9. (b) $7°$
10. (d) $53.13°$
11. (b) 198 μm
12. (a) $kg.m^2/s^2$
13. (a) water increases by decreasing the cross-sectional area of the nozzle
14. (d) zero, maximum
15. (c) emerges normal to the opposite face
16. (a) $\frac{1}{\sqrt{2}}$
17. (a) $\frac{1}{2}$
18. (c) $\frac{5}{1}$
19. (c) $\frac{\sin (90 - \phi)}{\sin \theta} = \frac{4}{3}$
20. (a) longitudinal
21. (c) when they encounters a sharp edge

### Second Answer the following questions

22. Because when the outside is dark, the amount of light passing from the outside is very small, so the person can see his image as a result of the reflection of the small amount of light reflected by the glass of the room's window and when there is light outside, the amount of light passing from outside is larger than the amount of the reflected light, so it is difficult for the person to see his image.

23. 


24. Because the angle of deviation depends on the refractive index of the prism for the light color and it is inversely proportional to the wavelength of the light, so as the wavelength of violet light is less than the wavelength of red light, hence the angle of deviation of violet light is larger than that of red light.

25. $\because \sin\phi_c = \frac{n_2}{n_1} = \frac{\lambda_1}{\lambda_2}$ $\qquad \therefore \sin\phi_c = \frac{\lambda_A}{\lambda_B} = \frac{450}{600}$

$\therefore \phi_c = 48.6°$

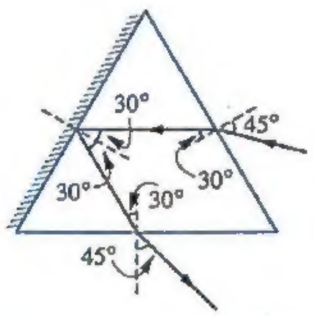
, and it is located in medium A

26. $\because Q_v = Av$ $\qquad \therefore \frac{V_{ol}}{t} = \pi r^2 v$

$\therefore \frac{m/\rho}{t} = \pi r^2 v$

$\therefore \frac{100/900}{25 \times 60} = \pi r^2 (0.2)$

$r = 0.1$ m

27. 


## Answer of General Exam 6

### First Choose the correct answer

1. (b) greater than the critical angle between the prism and the liquid
2. (d) 45°, $\sqrt{2}$
3. (c) changes, remains constant
4. (d) $\frac{1}{1}$
5. (a) 37°
6. (c) equal to 1
7. (b) sixth bright fringe
8. (b) 4.25 m
9. (d) 1.61
10. (b) 0.77 kg/s
11. (c) 23.8°, 45°
12. (b) 50°
13. (b) the temperature of the fluid
14. (d) ④
15. (a) x to z
16. (a) wavelength decreases to its half
17. (d) the wavelength of light in the first medium is smaller than the wavelength of light in the second medium
18. (d) 51°
19. (a) greater than 1
20. (c) interference
21. (c) the speed of the liquid at A is less than the speed of the liquid at B

### Second Answer the following questions

22. $\because \Delta y = \frac{4 \times 10^{-3}}{2} = 2 \times 10^{-3}$ m

$\because \Delta y = \frac{\lambda R}{d}$

$\therefore \lambda = \frac{\Delta y\, d}{R} = \frac{2 \times 10^{-3} \times 7 \times 10^{-4}}{200 \times 10^{-2}} = 7 \times 10^{-7}$ m

23. - The first angle of incidence $(\phi_1)$ = The angle of emergence $(\theta_2) = \phi_o$

- The first angle of refraction $(\theta_1)$ = The second angle of incidence $(\phi_2) = \theta_o$

24. The speed of water currents near the riverside is less than their speed in the middle of the river, so the aquatic plants could be seen at the slower currents region.

25. (a) $\upsilon = \frac{N}{t} = \frac{2048}{8} = 256$ Hz

(b) $T = \frac{1}{\upsilon} = 3.9 \times 10^{-3}$ s

26. The optically rarer material (which has less refractive index) is used to make the external layer of the optical fiber, so it can reflect the light that may escape from the inner core. So, the double layer fiber decreases the loss of light energy.

27. $\phi_1 = \theta_1 = 0°$ $\qquad , \qquad A = \phi_2 = 45°$

$\therefore 1.7 \sin\phi_2 = \frac{4}{3}\sin\theta_2$ $\qquad \therefore 1.7 \sin 45 = \frac{4}{3}\sin\theta_2$

$\therefore \theta_2 = 64.36°$

$\because \alpha = \phi_1 + \theta_2 - A$

$\therefore \alpha = 0 + 64.36 - 45$ $\qquad \therefore \alpha = 19.36°$

## Answer of General Exam 7

### First Choose the correct answer

1. (b) 10, 2
2. (b) 1000 s
3. (a) 1.41
4. (c) 0.03
5. (b) 60°
6. (b) 5 mm
7. (b) 2560 vibrations
8. (b) 21.73°
9. (b) 40.75°
10. (c) 1.75 N.s/m²
11. (c) 1.8 m/s
12. (c) A, C
13. (b) decrease
14. (a) 30°
15. (a) 6°
16. (d) 60 cm
17. (a) the absolute refractive index of glass is greater than the absolute refractive index of the other medium
18. (b) $\frac{1}{2}$
19. (b) less than one
20. (b) radio waves
21. (a) $n_2 < n_1$

### Second Answer the following questions

22. Because as the temperature increases, the viscosity of the fluids decreases, so honey flows faster in summer.

23. $\because \Delta y = \frac{\lambda R}{d}$ $\quad\therefore \lambda = \frac{\Delta y\, d}{R}$

$\therefore \lambda = \frac{4.5 \times 10^{-3} \times 0.1 \times 10^{-3}}{100 \times 10^{-2}} = 4.5 \times 10^{-7}$ m

24. $\because \sin \phi_c = \frac{1}{n}$

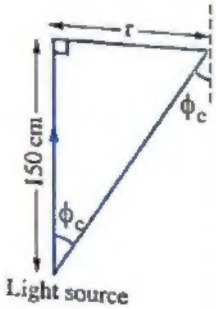
$\therefore \sin \phi_c = \frac{1}{1.33}$

$\therefore \phi_c = 48.75°$

$\because \tan \phi_c = \frac{r}{150}$

$\because \tan (48.75) = \frac{r}{150}$

$\therefore r = 171$ cm



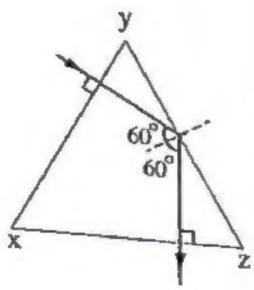

25. $\because \sin \phi_c = \frac{1}{n}$

$\therefore \sin \phi_c = \frac{1}{1.5}$

$\therefore \phi_c = 41.8°$

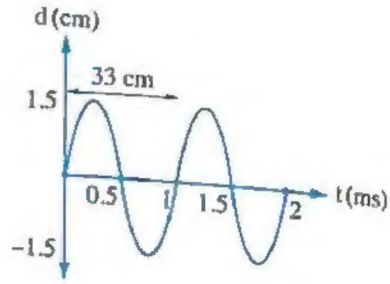
$\because \phi_2 > \phi_c$

$\therefore$ The ray will totally reflect inside the prism.




26. (a) Longitudinal wave.

(b)




27. $\because \theta_a > \theta_c > \theta_b$ $\quad\therefore n_a < n_c < n_b$

## Answer of General Exam 8

### First Choose the correct answer

1. (a) 30°
2. (d) X and Z
3. (d) red
4. (d) total internal reflection
5. (c) equal to one
6. (d) 24.6°
7. (c) 8°
8. (c) 48.59°
9. (d) doesn't change
10. (d) transverse, longitudinal
11. (b) 12.06°
12. (d) $\frac{4}{1}$
13. (b) 25.8°
14. (c) $\frac{5}{3}$ Hz
15. (a) material A
16. (a) greater than one
17. (c)
18. (a) $\frac{1}{7}$ hour
19. (a) $2 \times 10^{-3}$ s
20. (d) 90°
21. (d) $4\lambda_1$

### Second Answer the following questions

22. $\because \sin \phi_c = \frac{1}{n}$ $\quad\therefore \sin 42 = \frac{1}{n}$

$\therefore n = 1.49$

$\because \sin \phi = n \sin 25°$ $\quad\therefore \sin \phi = 1.49 \times \sin 25$

$\therefore \phi = 39.17°$

23. $\because \upsilon = \frac{v}{\lambda}$ $\quad\because \upsilon_1 = \upsilon_2$

$\therefore \frac{v_1}{\lambda_1} = \frac{v_2}{\lambda_2}$ $\quad\therefore \frac{v_1}{\lambda_1} = \frac{v_2}{\lambda_1 + 10}$

$\therefore v_1 (\lambda_1 + 10) = v_2 \lambda_1$ $\quad\therefore \frac{v_1}{v_2} = \frac{\lambda_1}{\lambda_1 + 10}$

$\therefore \frac{2}{3} = \frac{\lambda_1}{\lambda_1 + 10}$

$\therefore \lambda_1 = 20$ cm , $\lambda_2 = 30$ cm

24 $\because \tan\phi_2 = \frac{1}{4}$ $\therefore \phi_2 = 14°$

$\because \phi_2 = \theta_1 = 14°$ $\therefore \sin\phi_1 = n_2 \sin\theta_1$

$\therefore \sin\phi_1 = 1.6 \sin 14$ $\therefore \phi_1 = 22.8°$

25 $\because (\Delta y)_A = \frac{\lambda R_A}{d_A}$ $\therefore (\Delta y)_A = \frac{\lambda (0.6)}{0.15 \times 10^{-3}}$

$\therefore (\Delta y)_A = 4000\,\lambda$

$\because (\Delta y)_B = \frac{\lambda R_B}{d_B}$ $\therefore (\Delta y)_B = \frac{\lambda (0.8)}{0.175 \times 10^{-3}}$

$\therefore (\Delta y)_B = 4571\,\lambda$

$\because (\Delta y)_C = \frac{\lambda R_C}{d_C}$

$\therefore (\Delta y)_C = \frac{\lambda (0.8)}{0.15 \times 10^{-3}}$

$\therefore (\Delta y)_C = 5333\,\lambda$

$\therefore (\Delta y)_A < (\Delta y)_B < (\Delta y)_C$

26 (a) $\theta = 90° - 22° = 68°$

(b) $\because n = \frac{1}{\sin\phi_c}$ $\therefore n = \frac{1}{\sin 59}$ $\therefore n = 1.17$

27 To increase the flow speed of water at the nozzle of the hose where the flow speed of water is inversely proportional to the cross-sectional area based on the continuity equation, so the water rushing out of the hose can reach far distances. If the hoses are of wider nozzles, the water speed at the nozzle will decrease.

## Answer of General Exam 9

### First Choose the correct answer

1 (b)

2 (b) $\lambda_{violet} < \lambda_{red}$

3 (d) 336.6 m/s

4 (c) 45°

5 (b) 1.77 m/s

6 (b) 71.33° and it is located in the container medium

7 (b)

8 (a) greater than 1

9 (a) 3 cm

10 (c) 16

11 (b) Viscosity coefficient

12 (c) 60°

13 (d) the density of the liquid

14 (a) $\frac{1}{1}$

15 (d) 0.01 s

16 (a) 1.11

17 (a) 35.26°

18 (d) $\frac{y}{z-1}$

19 (c) $2.5 \times 10^8$ m/s

20 (a) fringes become more distant from each other

21 (c) 3

### Second Answer the following questions

22 Because the range of wavelengths of visible light extends from 400 nm to 700 nm which are very small wavelengths so that light diffraction doesn't appear because visible light needs very small aperture sizes for the appearance of light diffraction patterns.

23 As temperature decreases, the viscosity of the liquid increases, its resistance to the motion of a solid object inside it increases where the frictional forces between the liquid and the object increases.

24 $\because$ The two waves propagate in the same medium.

$\therefore v_1 = v_2$ $\therefore \frac{\lambda_1}{\lambda_2} = \frac{T_1}{T_2}$

$\therefore \frac{\lambda_1}{\lambda_2} = \frac{\frac{1}{2} T_2}{T_2}$ $\therefore \frac{\lambda_1}{\lambda_2} = \frac{1}{2}$

25 $\because$ The light ray deviates by an angle of 28°

$\therefore \theta_2 = \alpha + A = 28° + 35° = 63°$

$\therefore n \sin\phi_2 = \sin\theta_2$

$\therefore n = \frac{\sin\theta_2}{\sin\phi_2} = \frac{\sin 63}{\sin 35} = 1.55$

26 (a) $(\alpha_o)_r = A(n_r - 1) = 8(1.5 - 1) = 4°$

$(\alpha_o)_b = A(n_b - 1) = 8(1.55 - 1) = 4.4°$

$\therefore (\alpha_o)_y = \frac{(\alpha_o)_b + (\alpha_o)_r}{2} = \frac{4 + 4.4}{2} = 4.2°$

(b) $(\alpha_o)_b - (\alpha_o)_r = 4.4 - 4 = 0.4°$

27 (a) ${}_w n_o = \frac{n_o}{n_w} = \frac{1.8}{\frac{4}{3}} = 1.35$

(b) $\because n_w \sin\phi_1 = n_o \sin\theta_1$

$\because \frac{4}{3} \sin 60 = 1.8 \sin\theta_1$ $\therefore \theta_1 = 39.9°$

$\because \theta_1 = \phi_2 = 39.9°$ $\because \sin\phi_c = \frac{1}{1.8}$

$\therefore \phi_c = 33.75°$ $\therefore \phi_2 > \phi_c$

$\therefore$ The ray will not refract into air.

## Answer of General Exam 10

### First Choose the correct answer

1. (b) 4 N
2. (a) 0.003 m
3. (d) 1.66
4. (d) 1.75
5. (d) $3 \times 10^{-3}$, 12
6. (b) 100, 30
7. (a) remains constant
8. (d) 1.2 mm
9. (d) 75°, 60°
10. (b) 48.59° in medium Y
11. (c) 1.72
12. (c) the distance between the two slits increases
13. (a) emerge tangent to this face
14. (a) 0.2 cm/s
15. (a) greater than 1
16. (d) Mechanical energy
17. (b) the first angle of incidence
18. (a) the wavelength increases
19. (a) 25
20. (b) Diffraction
21. (a) 30

### Second Answer the following questions

22. $\because \lambda = \frac{v}{\upsilon}$ $\quad \because d = \lambda N$

$\therefore d = \frac{v}{\upsilon} N = \frac{340}{102} \times 12 = 40$ m

23. $\because \sin \phi_c = \frac{1}{n}$ $\quad \therefore \sin \phi_c = \frac{1}{1.65}$

$\therefore \phi_c = 37.3°$

24. In medium and uniform speeds air resistance resulting from air viscosity is directly proportional to the speed of the moving body and when the speed exceeds a certain limit, the air resistance becomes directly proportional to the square of the speed and not the speed itself leading to a noticeable increase in fuel consumption, so the driver has to consider not exceeding such limit (80 – 90 km/h).

25. At position O

26. $\because \theta_1 = 90 - \phi_2$

$\because \phi_1 = \phi_2$

$\therefore \theta_1 = 90 - \phi_1$

$\because \sin \phi_1 = 1.33 \sin \theta_1$

$\therefore \sin \phi_1 = 1.33 \sin (90 - \phi_1)$

$\therefore \sin \phi_1 = 1.33 \cos \phi_1$

$\therefore \tan \phi_1 = 1.33$

$\therefore \phi_1 = 53°$

$\therefore \theta_1 = 90° - 53° = 37°$

27. (a) $\because n \sin 30 = \sin 49$

$\therefore n = 1.5$

(b) $\because \sin \phi_1 = 1.5 \sin 35$

$\therefore \phi_1 = 59.36°$

$\therefore \alpha = \phi_1 + \theta_2 - A$

$\therefore \alpha = 59.36 + 49 - 65 = 43.36°$